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Contributed by Members of the Technical Staffs of the Works and Research Laboratories of the Company.

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THE NEW HEAVY ENGINEERING WORKS.

The New Heavy Engineering Works at Witton

INTRODUCTORY.

IT is universally recognised that greater productivity and a steady improvement in the standard of living depend upon an adequate supply of electric power, and the problem which faces every manufacturer of heavy electrical plant is to satisfy the ever-increasing demands both of industry and of the domestic consumer.

During the six years of war, almost the whole of the world's resources were absorbed in the production of armaments. Building of new power stations and, to a large extent, proper maintenance of existing plant ceased, with the inevitable result that the country is now faced with a vast programme of building new and bigger power stations and of replacing much of the existing generating plant which is rapidly nearing the end of its useful life.

Realising the important part The General Electric Co. Ltd. would be called upon to play in the fulfilment of this programme, the Directors decided to erect a completely new Works at Witton, Birmingham, the Company's largest group of factories devoted to the manufacture of heavy electrical equipment. The Transformer and High Tension Switchgear Works were also included in this scheme of extension, and a new Press Shop was laid down. Complementary extensions have been undertaken at the Company's Fraser and Chalmers Engineering Works at Erith, Kent, to afford increased capacity for the production of steam turbines, colliery winders and turbo-compressors.

The new Works at Witton was formally opened on November 9th, 1951, when senior officials from the British Electricity Authority, The National Coal Board, British Railways, The Steel Board, The Admiralty, Ministry of Supply, Air Ministry, and many representatives of the technical and national press were able to see this great building in production (fig. 2).

MANUFACTURING FACILITIES.

By reference to the plan shown in fig. 1 it will be seen that the layout has been designed for flow production, the construction and winding of the stators and rotors proceeding in parallel throughout the length of the assembly bay. These components eventually reach the test area and the final assembly of the machine takes place on the test bed. The facilities here available, which are described later in greater detail, are such that large steam turbine-driven alternators can be tested at full voltage and current, and both air-cooled and hydrogen-cooled machines can be run under operating conditions.

As soon as testing has been completed, the machines are dismantled, packed for shipment and leave the Works by the west door.

Flow production is also adopted in the winding bays, the finished stator and rotor coils being transferred to the assembly bay on flat rail trucks.

It is to be noted that this sequence of construction ensures a steady flow through the Works, eliminates congestion and results in a considerable saving of time with the result that it is expected that the total output of large generating plant, winder, rolling mill and ship propulsion motors will be almost doubled.

GENERAL DESCRIPTION.

Planned on the most modern lines and provided with the latest equipment, the new building, which covers a ground area of about 2½ acres, is capable of producing the largest turbo- and water-wheel alternators likely to be required

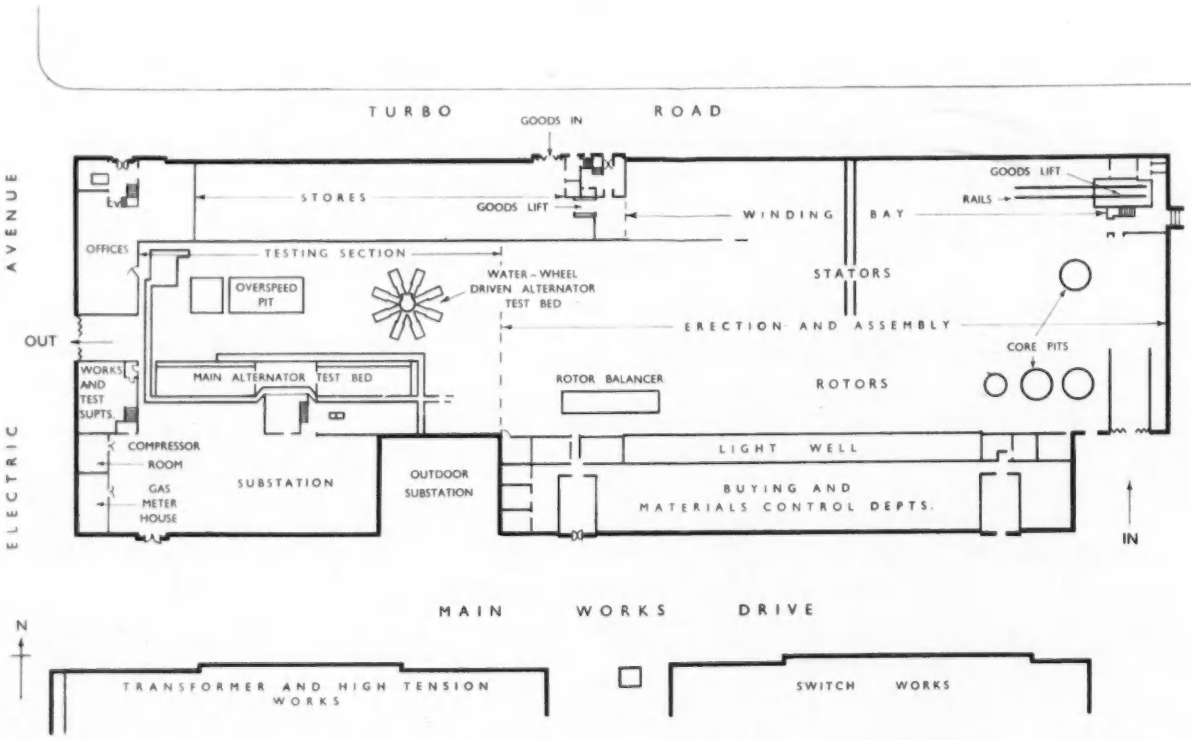

Fig. 1.—Block plan of the ground floor of the new Heavy Engineering Works.

for power stations for many years to come. Turbo-alternators up to 100 MW and even higher will be built and tested in this Works as well as large motors for rolling mills, winders and ship propulsion. The easing of the load on the other engineering shops will provide increased overall capacity for the manufacture of machines of all types.

A block plan of the building is shown in fig. 1. The main erection and test bay (fig. 3) is 525 ft. long by 100 ft. wide in a single span, the height to the eaves being 70 ft. Two overhead travelling cranes operate over the full length of the building and provide for a maximum lift of 220 tons.

At the east end are four core-building pits 6 ft. deep, each equipped with a hydraulic jack for compressing the core stampings. Three of these are designed for a total loading of 200 tons, and the fourth for 50 tons. Facilities are provided for ring flux testing of the cores both during assembly and when completed.

On the south side, and almost at the end of the erection section, is an electronic-controlled dynamic balancing machine, designed in the Company's Development Laboratory and capable of balancing rotors up to 50 tons in weight to an accuracy of a tenth of an ounce at the periphery.

Hitherto the dynamic balancing of large rotors has been a long and costly procedure, involving much skill on the part of the operator and occupying anything up to 50 hours. With the electronically-controlled balancing machine, which has been fully described in an earlier issue of this Journal,* complete calibration and balancing of a new rotor take only about one hour.

The various test beds (fig. 4), which include the raised bed for turbo-alternators, the overspeed rotor test pit and the test bed for water-wheel alternators, are situated at the west end of the bay and occupy a floor space of about 160 ft. by 100 ft.

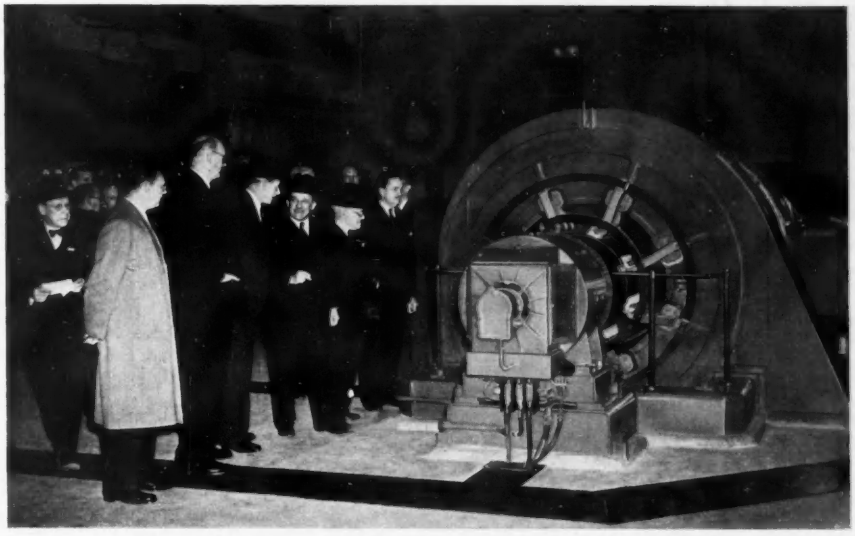

Fig. 2.—Sir Harry Railing, Chairman of The General Electric Co. Ltd., at the official opening.

The whole of the top floor (fig. 5) is used for the manufacture of stator coils and the formers used in this work. A 2-ton travelling crane runs the length of the stator coil section, a 5-ton dual-capacity lift at the east end of the building being provided to transport the coils to the ground floor.

The indoor substation, which houses the power plant and all associated switchgear required for test purposes and power distribution in this Works, is situated at the south-west of the building adjacent to the test beds, and covers an area of some 6,800 sq. ft. Immediately to the east of this building is an outdoor transformer and reactor substation.

* "An Electrical Dynamic Balancing Machine for Turbo-Alternator Rotors," by L. G. WARD, *G.E.C. Jour.*, Vol. XVII, No. 4, October, 1950.

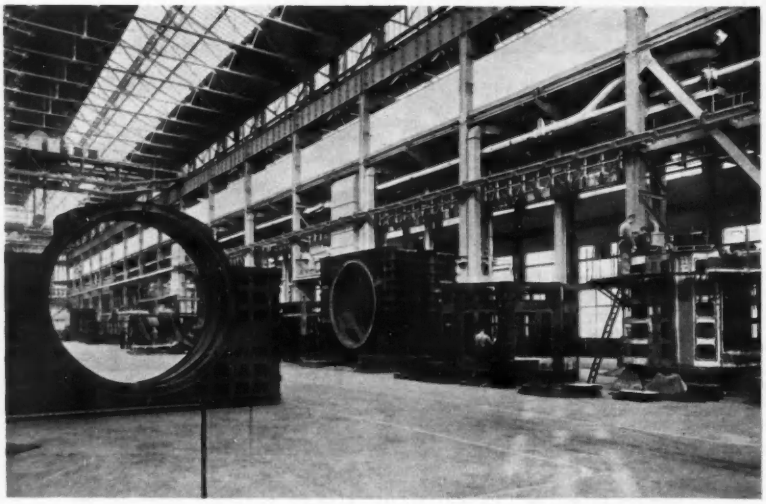

Fig. 3.—The main erection bay: hydrogen-cooled and water-wheel alternators in course of construction.

LIGHTING, HEATING AND VENTILATION.

Lighting of the main erection and test bay (fig. 6) is by means of 1,000 watt high-pressure mercury vapour discharge lamps supplemented by continuous lines of Osram fluorescent lamps along the sides and ends of the building. The average service illumination is 25 lumens per sq. ft., and even when the two cranes are operating in tandem for lifting heavy loads the overlap between the high level and tubular lighting is such that, immediately below the cranes, this figure drops only to 18 lumens per sq. ft.

The heating and ventilating system is designed to maintain a temperature of 65 degs. F. in the Works with an outside temperature of 32 degs. F. The heaters are of the unit blower type supplied

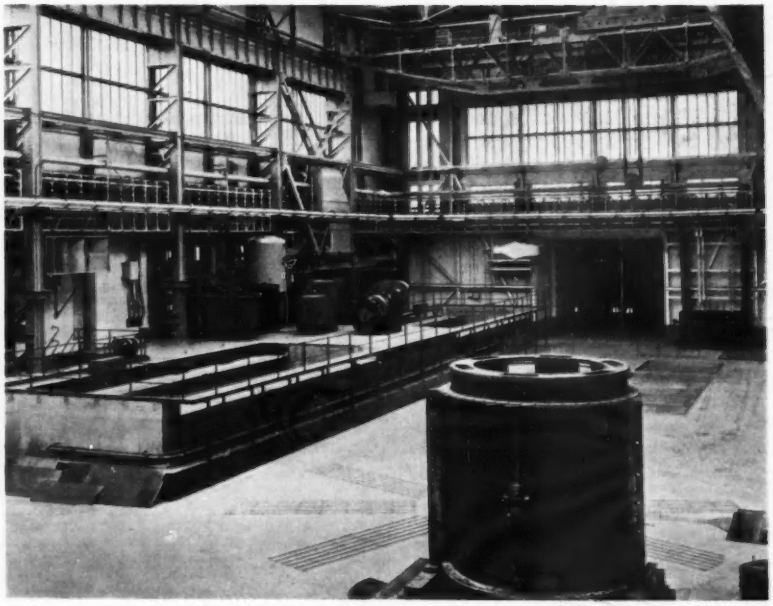

Fig. 4.—General view of the test beds. In the foreground is a stator for a 60 MW turbo-alternator.

Fig. 5.—Production of stator coils on the top floor of the building.

with steam from the low-pressure ring main. The total heating load is over 12½ million B.Th.Us an hour.

TEST EQUIPMENT.

Alternator Test Bed.

The main test bed for the turbine-driven alternators (fig. 7) is 133 ft. long by 19 ft. wide, and comprises a central platform 8 ft. high on either side of which is an alternator bed 50 ft. 6 ins. long and 6 ft. 3 ins. above the shop floor. With this arrangement, one machine can be erected or dismantled while a second is on test, thus enabling testing to proceed virtually without interruption.

Each of the alternator beds is so built as to form a pit below the machine and is provided with air ducts for the closed circuit ventilation of air-cooled alternators. A hydrogen detraining tank forms part of the test equipment enabling hydrogen-cooled alternators to be run under operating conditions.

Arrangements are made whereby all alternators can be tested at full voltage and current, two saturable reactors being provided so that loads up to 100 MVA at very low power factor can be imposed on the machines.

Fig. 6.—Night view in the main erection and test bay showing the even illumination.

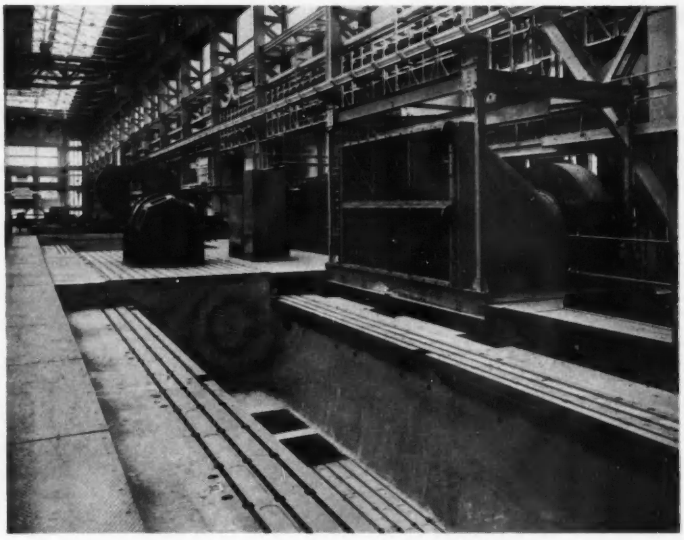

Fig. 7.—The test bed for turbine-driven alternators showing the driving motor and the removable platform on which are mounted the fans and cooler for air-cooled alternators.

Tubular copper busbars, 4 ins. diameter, connect the alternator to the reactors. These bars are suitable for voltages up to 22 kV, their large diameter minimising skin effect and eliminating any risk of corona.

Particular attention has been given to the lubrication system. In the event of a breakdown of the oil pumps, a header tank, designed for a working pressure of 50 lbs. per sq. in. and having a capacity of over 2,000 gallons, ensures an adequate supply of oil to the bearings during the time taken to shut down the plant.

For complete tests, constant speed with no risk of overspeed is essential. For this reason the driving motor, which is mounted on the central platform, is of the induction type, connected through two induction regulators and a 2,000 kVA step-down transformer to the 11 kV supply from the Midlands Electricity Board. The regulators give a variable voltage from 0 to 760 volts to meet the requirements of starting and stopping the plant on test. They may also be used to provide a supply when reactance measurements of the stator windings are being made. The motor is rated at 2,000 h.p. 2,950 r.p.m. and has a double shaft extension so that it can be coupled up readily to alternators mounted on either of the test beds. In the event of greater driving power being required a second motor can be coupled in tandem.

A steel platform extends the full length of the test bed on the south side and two removable sections, each 20 ft. 6 ins. long by 13 ft. 9 ins. wide, are provided adjacent to the alternator beds. On one are mounted the fans and coolers for the ventilating system of air-cooled alternators, on the other, the hydrogen and CO_2 control panels, gas supplies and so forth for hydrogen-cooled alternators. These platforms can be interchanged as required. The control board from which the whole of the test plant is operated is situated on the steel platform alongside the middle section of the test bed.

Fig. 8.—Steel reinforcement in the overspeed pit.

Rotor Overspeed Pit.

The overspeed pit is situated at the north end of the test area, and is designed to accommodate the rotors of turbine-driven alternators. It is of heavily reinforced concrete construction and is over 60 ft. long by 11 ft. wide between the concrete sides. The arrangement of the steel reinforcement is shown in fig. 8, some 300 tons of steel being used.

Over a length of 37 ft. 6 ins. the sides of the pit are protected by steel boxes filled with sand and set in panels 5 ft. 6 ins. deep. A final facing of timber, 10 ins. thick, completes the provision made to absorb the huge amount of energy which would be released in the unlikely event of a large rotor bursting on overspeed. An escape tunnel with entrances at each end extends the full length of the pit. The pit is completely covered by seven slabs, each weighing 30 tons and constructed from rolled steel joists and thick flange plates, the box section thus formed being filled with concrete. A sand-filled steel box, faced with thick timbers, forms the underside of the slab. Heavy cast-iron wedges secure the slabs so that the entire covering is dovetailed in position. Ventilation is provided by a centrifugal fan which draws air from the pit and discharges it to atmosphere. A general view of the inside of the pit is shown in fig. 9.

Since variable speed is essential for overspeed testing, a D.C. motor under Ward-Leonard control drives the rotor through speed increasing gears. The motor is rated at 2,000 h.p. and is designed for a voltage range of 0/600/750 volts and for speeds up to 900 r.p.m. With this method of control rapid starting and stopping can be achieved, and full use made of the power regenerated when the test is being shut down. The motor and gearing are mounted on a bedplate to form a self-contained transportable unit which can be lifted readily from the pit and used to drive a variable frequency alternator for the overspeed testing of water-wheel alternators.

Lubrication arrangements are similar to those provided for the main test bed.

The test control board is mounted on floor level to the west of the pit and is of the flat back type.

Water-Wheel Alternator Test Bed.

This test bed (fig. 10) comprises a central pit 8 ft. in diameter, and 6 ft. 6 in. deep from which radiate cast-iron floor plates arranged symmetrically to form eight legs on which the alternator and test equipment are mounted. It will accommodate vertical shaft slow speed alternators up to approximately 44 ft. external diameter with rotors weighing up to 200 tons.

At the bottom of the pit is a 100-ton hydraulic jack on which is mounted a ball bearing to carry the weight of the alternator rotor on starting. As soon as rotation begins and oil enters the Michell thrust bearing of the alternator, the jack is released.

The tests which are undertaken for water-driven alternators include the determination of open and short circuit characteristic curves and the measurement of losses, as well as overspeed testing.

Fig. 9.—Inside the overspeed pit showing the heavy timber facing and the driving motor.

A 2,000 h.p. D.C. driving motor is mounted on top of the alternator in place of the exciter. It is Ward-Leonard controlled and provides a speed range from 0 to 800 r.p.m. so that in many cases it can be used for overspeed tests. Where higher speeds are required, the alternator, with its exciter, is run as a synchronous machine and is supplied with variable frequency power from an alternator rated at 5,000 kVA, 5,000 volts, with a frequency range up to 150 c/s. The alternator is driven by the 2,000 h.p. geared D.C. motor, normally used in the overspeed test pit.

Substation Equipment.

The power plant for all test

requirements, which includes two motor generators, two induction regulators and a grid-controlled rectifier, is housed in the indoor substation together with the high- and low-voltage switchgear for test and Works supplies. Immediately to the east of this building is the outdoor substation where seven transformers and two saturable reactors are installed. Two air-blast water spray coolers are also situated in this area. One deals with the water from the oil cooler and the hydrogen and air coolers in the closed ventilating circuits of the alternators on test; the other cools the electrolyte from the liquid starter for the 2,000 h.p. driving motor on the alternator test bed.

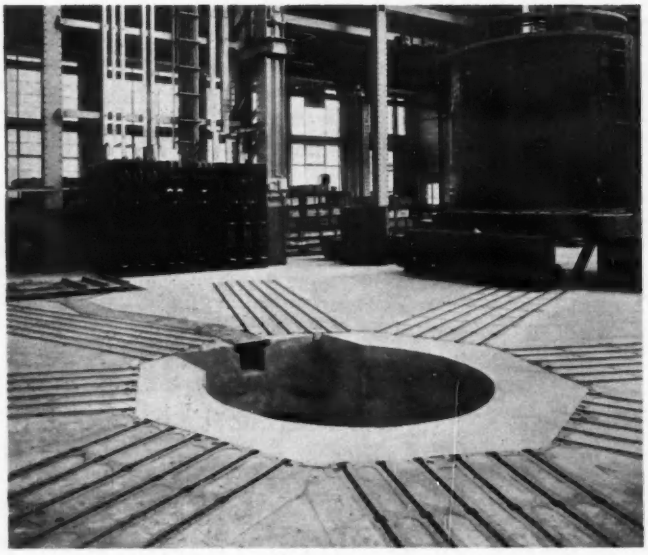

Fig. 10.—Test bed for water-wheel alternators with the control board in the background.

Three incoming supplies are available :

(*a*) Two 11 kV feeders, one from the Midlands Electricity Board's network and the other from the Works Power Station.

(*b*) A 460 volt, three-wire D.C. supply for the cranes and general Works services.

(*c*) A 400 volt, three-phase, four-wire, supply. This is an emergency feeder for essential test plant auxiliaries, and is brought into service automatically in case of failure of the main supply.

Motor Generator Sets.

The main power unit comprises a 750 h.p. 440 volt, synchronous induction motor directly coupled to a 4,000 kVA alternator, a 2,000 kW D.C. generator and two exciters. The motor is connected to the 11 kV supply through a 750 kVA step-down transformer. The alternator is specially wound to generate at voltages of 11 kV, 6·6 kV, 5·5 kV or 3·3 kV according to the stator connections used. Forced ventilation is employed, the air being drawn from the substation and exhausted through ducts either into the test bay or to the outside atmosphere by a 45-inch "Sirocco" fan driven by an 80 h.p. motor.

This plant has two main functions. First it can be run as a motor-generator for the Ward-Leonard control of the 2,000 h.p. motor in the overspeed test pit or of the driving motor for water-wheel alternators. When so used, the alternator is connected to the 11 kV supply and operates as a synchronous motor to drive the 2,000 kW D.C. generator, the 750 h.p. motor being used solely for bringing the set up to synchronous speed.

Second, the 4,000 kVA machine may be driven as an alternator for supplying current for ring flux tests of stator cores and for stator reactance measurements. In both cases the power factor is very low so that the 750 h.p. synchronous induction motor will usually provide sufficient driving power. If necessary, additional power can be obtained by running the D.C. generator as a motor, in which case it is connected to the D.C. Works supply.

For providing the excitation current for machines on test, a 360 kW, 400 volt motor generator is installed. The driving motor is of the slipring type rated at 550 h.p. and operates on the 440 volt A.C. supply. This plant also supplies direct current for heating the rotor windings during the manufacturing process of compressing them in the slots.

Provision is made for installing a further motor-generator at a future date. This unit will comprise a 4,000 kVA synchronous machine directly coupled to a 2,000 kW D.C. generator.

Either machine can be used for driving so that the set can provide a D.C. supply or a variable frequency A.C. supply as required.

Induction Regulators.

A variable voltage A.C. supply for the 2,000 h.p. driving motor on the alternator test bed is obtained from a 2,000 kVA, 11,000/380 volt outdoor transformer in conjunction with two motor-operated induction regulators. Each is rated at 500 kVA and provides a voltage range from 0 to 760 volts.

Saturable Reactors.

The two outdoor saturable reactors for loading alternators on test are rated at 75 MVA at 22 kV and 11 kV, or 37 MVA at 6·6 kV. They can also operate at 100 MVA at 15 kV on a three-hour rating. Direct current for saturating the reactors is obtained from a 325 kW, grid-controlled, pumpless, steel tank rectifier situated in the indoor substation.

Transformers.

In all, there are seven transformers in the outdoor substation, all of which operate at 11 kV. The largest of these is rated at 4,000 kVA and provides the heavy current A.C. supplies to the test bay. It receives power from the 4,000 kVA alternator of the main motor-generator set in the indoor substation. The secondary winding can be connected in star or delta by means of a change-over isolator to give a voltage of 880 or 500 volts.

Three transformers, two rated at 1,000 kVA and one at 500 kVA are installed for the 440 volt A.C. distribution system, while a 750 kVA unit supplies power to the 750 h.p. driving motor of the main motor-generator set. The two remaining units supply the induction regulators and grid-controlled rectifier and are rated at 2,000 kVA and 600 kVA respectively.

Switchgear.

The whole of the switchgear in the indoor substation is situated along the north and south walls of the building. An eight-panel metalclad switchboard, with breakers of 250 MVA capacity, controls the two incoming 11 kV feeders and the six outgoing feeders to the power transformers. The switchgear is remotely operated from a control and metering board in the substation. For the 440 volt A.C. distribution system, and for all essential test auxiliaries, an eighteen-panel air-break switchboard is installed. The various

Fig. 11.—A 200-ton double-crank precision bending press in the new extension of the High Tension Switchgear Works.

panels are in single, double or four-tier form, dependent upon the size of circuit breaker and type of equipment involved. This design of switchgear is widely favoured for controlling auxiliaries and is used extensively in modern power stations.

Fig. 12.—One of the main bays in the power press section of the Press Shop.

A flat back switchboard is provided for the heavy current A.C. and D.C. supplies to the test beds and core pits, and for the 460 volt D.C. distribution system.

ELECTRICAL DISTRIBUTION SYSTEM.

The power cables and heavy current busbars in the main erection and test bays are supported from the stanchions at high level. The heavy current busbars are of aluminium strip or channel depending upon the current capacity. All busbars are painted a matt black to assist radiation and thus increase their current-carrying capacity.

For essential house services such as Works lighting, office fans and the like, the totally enclosed "plug in" busbar system is used. The busbars are enclosed in a sheet metal casing with tap-off units at 3 ft. intervals, and are situated along each side of the Works above the crane walkway.

MACHINE TOOLS.

It will be evident from what has been said that the new Heavy Engineering Works will be used exclusively for assembly and testing, machining operations being performed in the older engineering Works. Many new machine tools have already been brought into service; others are in course of installation or on order. They include several heavy duty lathes, one of which has 60 in. centres and is able to handle work up to 20 ft. in length, and another with 42 in. centres and 45 ft. between centres; vertical boring mills with tables ranging from 6 ft. to 25 ft. diameter; horizontal borers with 26 ft. horizontal travel, one of which has a 12 ft. vertical travel; heavy duty planers; and, in particular, a two-spindle plano-miller 7 ft. 9 ins. between uprights with a 16 ft. horizontal and 6 ft. vertical travel.

THE TRANSFORMER WORKS EXTENSION.

The provision of more generating plant is necessarily followed by a corresponding increase in the demand for transformers, particularly those of 10,000 kVA upwards, and it was evident that this could be met only by extending the existing Transformer Works. Accordingly a

further 175 ft. has been added to the main erection bay which is 60 ft. wide and 55 ft. high to the eaves. The new portion is served by the existing 50-ton crane, two 30-ton cranes, and twelve new jib cranes, each of 20 ft. radius and 2-ton capacity.

A new drying stove has been built into the east wall, and projects into the adjacent bay. It will accommodate transformers up to the largest sizes, and is loaded by trucks running on multiple rail tracks. Heating is by steam in conjunction with forced air circulation, and facilities are provided for vacuum drying within the oven.

Additional oil treatment plant and oil storage tanks are installed, together with pumping equipment for feeding the oil to various distribution points throughout the main bay.

To house the core preparation section, the west bay has also been extended by 175 ft., while to the east of the main erection bay a new two-storey bay, 275 ft. long by 60 ft. wide, has been built. The ground floor serves partly as a dispatch department for the Transformer Works and partly as the new High Tension Switchgear stores. On the upper floor are the light winding and assembly sections.

The additional manufacturing floor space and the improved layout which has been made possible contribute to the greatly increased capacity now available for the manufacture of transformers, which is thus kept in step with the output of generating plant.

THE HIGH TENSION SWITCHGEAR WORKS EXTENSION.

The extensions to the High Tension Switchgear Works were made necessary by the rapidly growing demand for circuit breakers with capacities exceeding 2,500 MVA and for service at voltages up to 275 kV. The main assembly bay, which is 60 ft. wide, has been extended by 300 ft., of which the first 125 ft. continues at the same height as the existing building. Over a considerable length, the height of the building has been increased in order to give the headroom necessary in the production of very high-voltage breakers.

To the east of the assembly bay is the fabrication section (fig. 11), which has also been extended by 175 ft., and is served by three 5-ton cranes. The additional floor space has permitted a complete reorganisation of the fabrication shop for flow production, and new presses of the latest type have been installed. The ventilation system in this bay allows for twenty changes of air an hour and is designed to dispose of the fumes from the welding cubicles. A sheeted partition between the fabrication and assembly bays prevents air being drawn from the adjacent main assembly bay.

THE PRESS SHOP.

The press shop, sheet metal stores, tool room with its drawing office, as well as the tinsmiths shop are being centralised to form a self-contained feeder works.

Improved manufacturing methods have been introduced, and the layout planned for flow production from the raw material stores to the final stampings and pressings for the various Works on the Witton site. As a direct result of this reorganisation a considerable increase in output has been achieved.

The power press section occupies a floor area of 41,000 sq. ft. and provides an annual output of over 3,500 tons of stampings of all sizes; one of the main bays is shown in fig. 12. The equipment includes two 8 ft. hydraulic guillotines, "Insulining" machines of improved design, sixty-three blanking presses ranging from 10 tons to 200 tons capacity and forty-five notching presses with a maximum operating speed of 960 notches per minute. Two large gallery presses are installed for notching segmental laminations for cores up to 20 ft. in diameter.

Fork trucks of 2-ton capacity operating in conjunction with their associated crates and pallets handle the materials and tools, while an overhead crane provides additional lifting facilities in the heavy press bay. Adequate space for manoeuvring the trucks is afforded by the wide gangways.

Electrical Progress and Development

Contributed by Members of the Technical Staffs of the Works and Research Laboratories.

POWER EQUIPMENT.

Turbo-Generators and Compressors.

THE increasing tempo of industry, due both to intensification of the export drive and the incidence of the rearmament programme, has naturally added to the demand for power plant at home and overseas.

During the year further contracts have been made with the British Electricity Authority for three additional 75,000 kVA, 11·8 kV, 3,000 r.p.m. hydrogen-cooled turbo-alternator sets. Two of these are for the Hams Hall "C" Station, Birmingham, and one for the new station at Ince for the Merseyside and North Wales Division. Taken in conjunction with the sets already in hand, these orders will result in each of these stations being equipped with three hydrogen-cooled units of this capacity. In all, twelve such sets are now in course of construction.

Other contracts for generating plant for home use include a fifth 37,500 kVA, 22 kV set for Woolwich and two 37,500 kVA, 11 kV sets for Huncoat Power Station, Accrington, bringing the number on order for this station up to a total of four. There is also a pass out, geared, turbo-alternator set for Keynsham Paper Mills

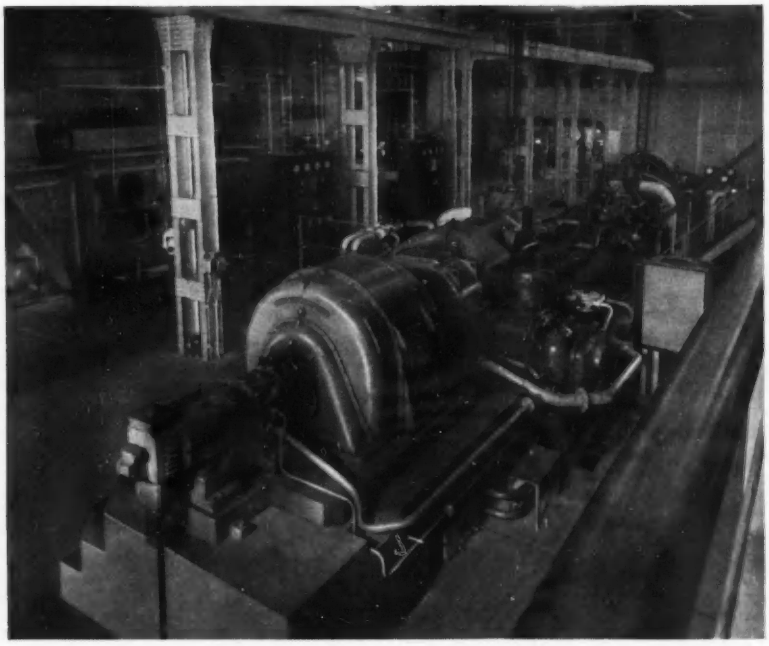

Fig. 1.—The power station at Travancore Rayons, Ltd., India, showing two 1,500 kW geared turbo-alternator sets. The alternators are totally enclosed and arranged for a closed circuit system of ventilation.

rated at 2,000 kW, 3·3 kV, 1,500 r.p.m. A number of turbo-alternators and turbo-generators are also on order for marine use, mostly in tankers, particulars of which are given in the section dealing with marine electrical equipment.

From the Millom and Askam Hematite Iron Company, Cumberland, an order has been received for a high-pressure turbo-blower designed to deliver 45,000 cu. ft. of air per minute against a pressure of 12 lbs. per sq. in. gauge. Among the plant put into service this year at the Margam Works of the Steel Company of Wales are a 60,000 cu. ft. turbo-blower and an 8,000 kW turbo-alternator. Other generating plant and turbo-blowers are at present in course of erection at these works.

In the export field much equipment has been supplied to, and is on order for, the Dominions and Colonies. From Bloemfontein, South Africa, a further order has been received for two 11,800 kVA, 11 kV high-pressure turbo-alternator sets ; for the Demerara Electric Co., British Guiana, a 6,250 kVA, 4 kV, high-pressure set ; and two 3,125 kVA, 6·6 kV geared sets for Mackay City Council, Australia. In all these stations the Company already has generating equipment supplied under earlier contracts.

For the Harmony Gold Mining Co. of the Rand Mines there is on order a turbo-compressor to deliver 20,000 cu. ft. of air per min. at 92 lbs. per sq. in. The compressor is driven through gearing at 5,000 r.p.m. by a 3,935 h.p., 6·6 kV synchronous motor running at 1,500 r.p.m. The order also includes two 275 h.p., 6·6 kV slipring motors for driving mud pumps and two 6·6 kV, 150 MVA switchboards together with a control desk. A third motor-driven blower for the Iron and Steel Corporation of South Africa is being installed and two 2,000 kW high-pressure turbo-generator sets are on order for Vryheid Coronation Colliery. During the year the fourth 47,500 kVA turbo-alternator set for the Orlando Power Station, Johannesburg, has been put into commission and the fifth machine has been despatched. Five further sets of 37,500 kVA are also in hand for this station.

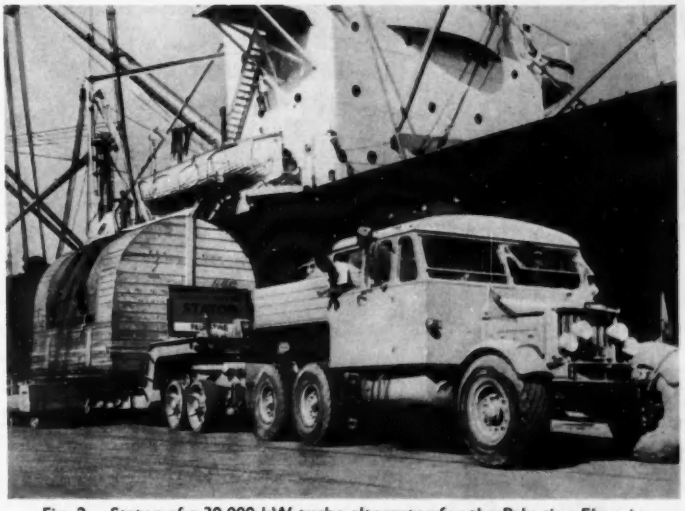

Fig. 2.—Stator of a 30,000 kW turbo-alternator for the Palestine Electric Corporation at Haifa Dock.

Other equipment commissioned during the period under review comprises two 9,375 kVA, 11 kV turbo-alternator sets for the Wide Bay Electricity Authority, Queensland, a 5,400 kVA, 6·6 kV geared set for the Athens Electric Company, three 1,000 kW, 400 volt geared sets for the United Africa Company at Insu on the Gold Coast and two 1,000 kW, 550 volt geared sets for West Bokaro Ltd., Calcutta. A 30,000 kW turbo-alternator set has been delivered to the Haifa Power Station of the Palestine Electric Corporation (fig. 2), while for the Allenwood Station, of the Eire Electricity Board, a 25,000 kVA, 10·5 kV turbo-alternator has been delivered and is in course of erection (fig. 3).

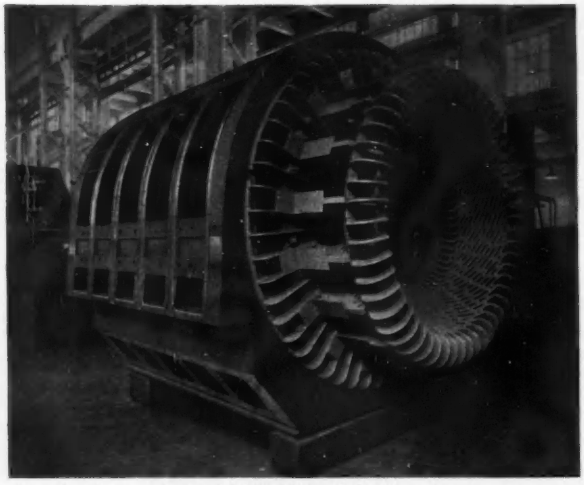

Fig. 3.—Stator of the 25,000 kVA 10·5 kV turbo-alternator for Allenwood Power Station, Eire.

Control of Alternators.

Six prototype equipments for static control of alternators have been completed for the Ministry of Supply; three of these are for 10 kVA and three for 15 kVA machines. The voltage stabilisers serve the dual purpose of exciter and voltage regulator and are completely devoid of any moving parts or valves. A resonant circuit supplies the alternator field by way of a transformer and rectifier and ensures automatic self-excitation to the correct open circuit value. A series coil on the transformer carries the alternator load current and provides a compounding component of secondary current which takes account of load and power factor. In this newly developed system the number of essential components in the stabiliser is reduced to three : capacitor, transformer and rectifier.

Transformers and Reactors.

For the Huddersfield Station of the British Electricity Authority there are on order two 45,000 kVA, 132/33 kV transformers and two 37,500 kVA, 11·8/35·7 kV generator transformers. For the Whitehead Iron and Steel Company Ltd., two 20,000 kVA, 33/6 kV outdoor type transformers are in course of construction in addition to six outdoor reactors with a 3 per cent reactance on a throughput of 4,600 kVA and one outdoor type reactor with a reactance of 1·5 per cent on a throughput of 4,000 kVA. The construction of two 45,000 kVA, 132/66 kV transformers for Cheltenham has been completed.

Fig. 4.—The second of six 70,000 kVA generator transformers for the Uskmouth Power Station of the B.E.A. leaving the Works.

The second of six 70,000 kVA generator-transformers for the Uskmouth Station of the British Electricity Authority has now been delivered to site. The conveyance of large pieces of equipment of this type is frequently a matter of some difficulty; it is thus of interest to record that, in this instance, the weight of the transformer was reduced from 131 tons to 110 tons by the expedient of removing the oil and filling the tank with inert gas, thereby enabling road transport to be used throughout the entire journey (fig. 4). One of these transformers completely assembled and ready for dropping into its tank is seen in fig. 5.

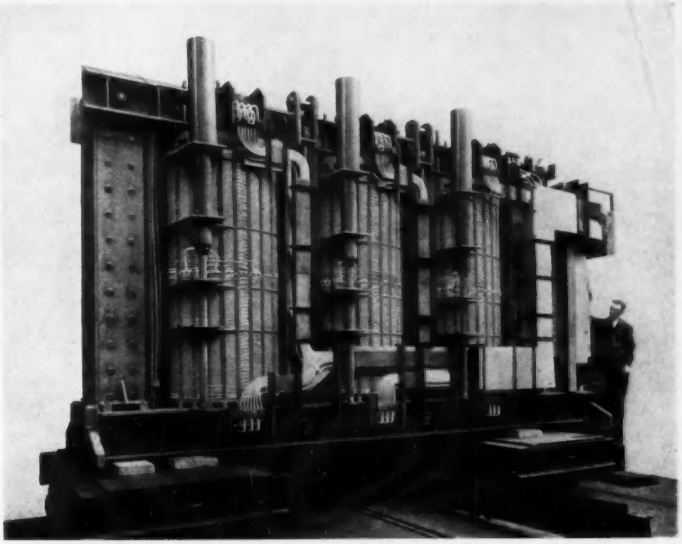

Fig. 5.—70,000 kVA, 11·8/140·7 kV generator transformer for Uskmouth, completely assembled and ready for lowering into its tank.

The considerable number of export orders now in hand include twenty-five outdoor transformers, both 132 kV and 66 kV, for the Government of India. These transformers of a total capacity of 160,000 kVA, are required for the Hirakud Dam Project for which the Company is also supplying a large quantity of outdoor switchgear. For the Saltos del Sil Power Authority, Spain, there are on order three 16,000 kVA, 6·6/138 kV outdoor type transformers.

A notable advance in the field of measurement and protection has been the development and production of a prototype 132 kV fully impulse-tested voltage transformer at the Chamberlain & Hookham Works (fig. 6). The transformer complies in all respects with British Standard No. 81-1936, having an output of 500 VA, and an accuracy Class B. A tertiary winding is incorporated which, when suitably connected in a three-phase bank, can be utilised for earth-fault protection.

Another development of considerable interest is the use of reactors enabling single anode mercury arc rectifiers to operate directly on a three-phase supply without the use of an intermediate transformer. Where appropriate, such reactors are now included with the rectifier equipment.

A number of small transformers to be used for a system of overhead line protection, embodying high-voltage strength associated with definite speech transmission characteristics, have been supplied both to the Coventry Telephone Works and to the Pirelli-General Cable Works.

In certain situations it is highly desirable to employ transformers free from the risk of fire. For this purpose there have been built transformers similar to the ordinary oil-filled type but with class B insulation and a cooling arrangement in which air is used as the cooling medium, in place of oil, and is circulated by fans through the cooling tubes. A number of this type of transformer, using a specially designed air-to-air heat exchanger, are at present on order.

An improvement in the construction of rectifier transformers has been the substitution of

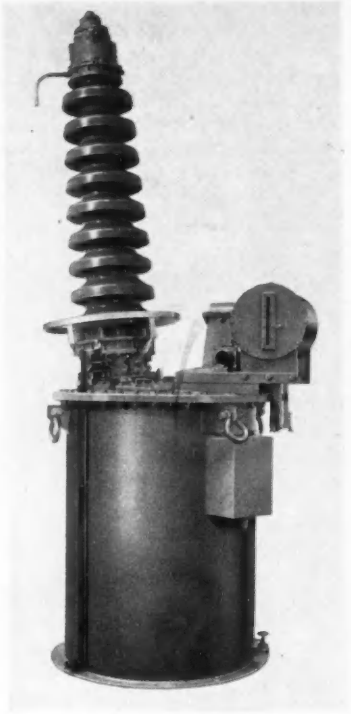

Fig. 6.—Prototype 132 kV, 500 VA, Class B voltage transformer.

flexible insulated cable for the rigid copper base connections used hitherto. The low-voltage side of a 1,500 kW rectifier transformer with flexible connections is seen in fig. 7.

Transformer Tapping Switches.

Some details of two new types of on-load tapping switches, N and B, were given in the last review of progress in this Journal in January, 1951. The type N switch has been further developed and has undergone extensive testing, including a mechanical test involving 30,000 operations. This switch is being fitted to a number of transformers at present on order.

The type J switch is already firmly established, the modified version, type M, is being used with several transformers under construction among which are those now being built for the Hirakud project.

Silica-Gel Breather.

The Company has, for some considerable time, been manufacturing and supplying with transformers silica-gel breathers of its own design. Such breathers have the advantage of avoiding the use of cartridges, employing instead a bulk of silica-gel in a loose granulated state. The provision of a full-length window enables the entire extent of the gel column to be inspected. Larger sizes of this type of breather are now in course of development, all of which continue to incorporate an oil seal.

Outdoor Switchgear.

Some important contracts for outdoor type switchgear, both for home and overseas customers, have been accepted in the course of the year. For the Meaford " B " Generating Station an order is in hand for the electrical equipment for a 132 kV, 12-bay outdoor substation which will include twelve 132 kV oil circuit breakers, each with a breaking capacity of 2,500 MVA. Much outdoor equipment has also been ordered by the Government of India in connection with the Hirakud Dam Project. The contract covers 132 kV, 66 kV and 33 kV switchgear for six complete outdoor substations and includes twelve 132 kV, 2,500 MVA oil circuit breakers as well as 11 kV metalclad gear for the local feeder switchboards. A contract from the Government of Madras covers 110 kV and 66 kV circuit breakers and equipment for three out-

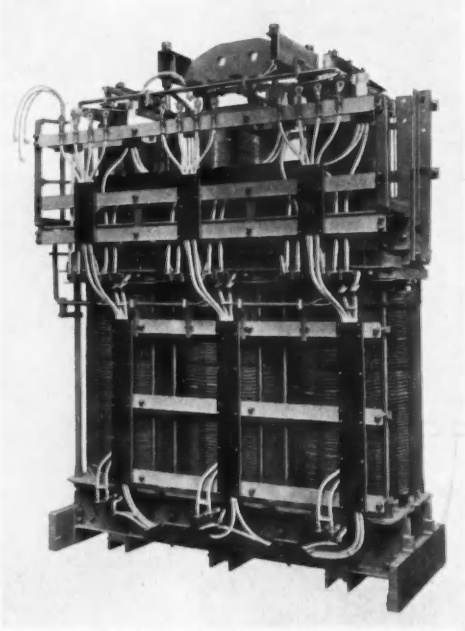

Fig. 7.—Low voltage side of a 6·6 kV, 1,500 kW, 600 volt D.C. rectifier transformer showing flexible connections.

door substations. Other export orders for outdoor equipment include seven 66 kV, 500 MVA oil circuit breakers for the State Electricity Commission of Victoria and 16-33 kV, 500 MVA oil circuit breakers for Blackdown Substation, Sydney County Council.

METALCLAD SWITCHGEAR.

Many home and overseas orders have been received for metalclad switchgear. A twenty-two-panel heavy duty metalclad switchboard, 33 kV, 1,000 MVA is in hand for the Homebush Substation of the Sydney County Council ; an eighteen - panel double busbar switchboard rated at 22 kV, 750 MVA for Swartkops Power Station, Johannesburg, and an eleven panel 11 kV, 1,000 MVA board for Nechells Power Station, Birmingham. One of the two 11 kV, 250 MVA boards recently commissioned at Nechells "B" Station is seen in fig. 8. For the London Electricity Board there is on order a seventeen-panel 33 kV, 750 MVA switchboard fitted with remote control equipment. The ten-panel 33 kV, 1,500 MVA board for the Clydes Mill Power Station of the British Electricity Authority is now in commission.

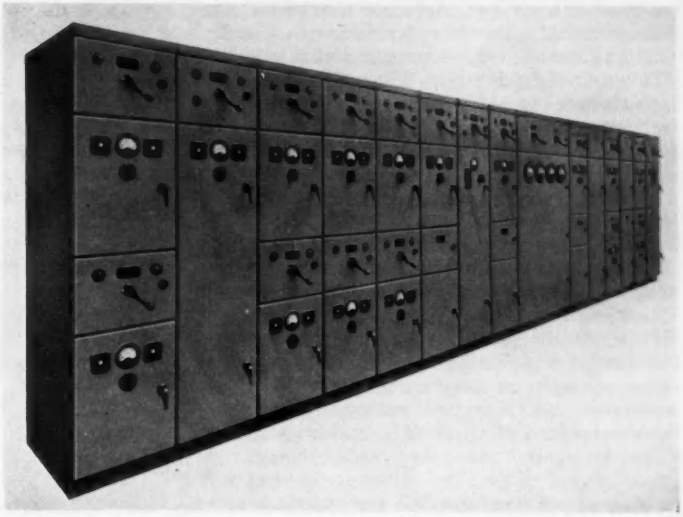

Fig. 9.—A fifteen-unit cubicle type contactor board for the coke preparation plant at the Nantgarw Colliery of the National Coal Board, South Wales.

Fig. 8.—One of two 11kV, 250 MVA metalclad switchboards, with circuit breakers rated from 400 to 2,000 amps. at Nechells "B" Power Station, Birmingham.

Orders for medium duty metalclad switchgear include a thirteen-panel switchboard rated at 250 MVA, 6·6 kV for the State Electricity Commission of Victoria, a seven-panel switchboard of a similar rating for the Sheepbridge Iron Co., Ltd., and a ten-panel board rated at 350 MVA, 6 kV for the Whitehead Iron & Steel Co. Ltd. The thirty-seven panel 6·6 kV board for the Tramway Section of the City of Glasgow Transport has now been installed.

A considerable amount of both

mechanical handling and electrical equipment has been supplied to the coke preparation plant of the National Coal Board at Nantgarw Colliery, South Wales. In fig. 9 is seen a fifteen-unit, four-tier, cubicle type contactor board controlling a group of eighteen totally enclosed, fan cooled, squirrel cage motors. An interior view of the incoming feeder control panel is shown in fig. 10.

Load Bias Busbar Zone Protection.

Tests have recently been carried out in the Works on the load bias busbar protective equipment which is being supplied for Staythorpe and other Power Stations. The switchgear protected is in a typical Grid substation, having a short circuit rating of 2,500 MVA. The tests provided an opportunity to stage a demonstration of the performance of this type of protective gear before representatives of the B.E.A. and consultants. The load bias protective gear is the latest development of the idea of biasing that was the basis of the original McColl protection ; it provides high-speed sensitive protection, not only against earth-faults, but also against phase-to-phase faults of a lower value than has hitherto been afforded by other schemes.

Primary current tests carried out were designed to show (1) stability of the equipment on all types of external fault up to 10,900 amps. (2,500 MVA) ; (2) the sensitivity of the equipment to all types of internal fault ; (3) the speed of response to internal faults ; (4) the sensitivity of the associated current transformer supervision equipment.

The heavy restraining torque exerted in the load bias relay under through-fault conditions was demonstrated, and oscillograph records were obtained showing an overall relay operating time (load bias relay and trip relay) of 2½ cycles with an internal fault of three times the effective setting. Effective settings of 120 per cent and 75 per cent were obtained for the least sensitive phase and earth-fault conditions respectively.

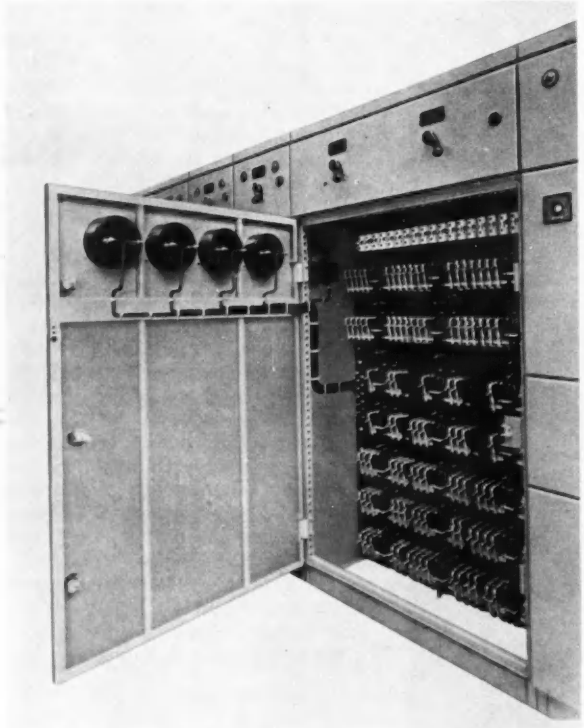

Fig. 10.—Interior view of the incoming feeder control panel on the board shown in fig. 9.

Surge-Proof Intertripping Relay.

A surge-proof relay, type M.C.T. (fig. 11) has been developed for use in circuit breaker intertripping schemes. This relay discriminates between the D.C. intertripping signal and any alternating current which may be flowing in the pilots ; it can be used in conjunction with either protective gear pilots or with pilots which are for the exclusive use of the intertripping scheme. The main detecting element is a double moving coil relay supplied through a special circuit comprising a transformer, rectifier and resistors. Alternating current in the pilot circuit gives a bias to the relay setting, but the design is such that the relay will operate when receiving its D.C. signal at the same time as A.C. up to 5 amps. The operating time of the relay is 0·07 seconds.

Cables.

A development by the Pirelli-General Cable Works is the Pigebestal and Pigebesteel cables, which are insulated with a special quality asbestos paper and are sheathed, respectively, with welded aluminium and welded stainless steel. The cables are either single or multicore and are designed for voltages up to 660. They are resistant to fire, non-inflammable, non-ageing and maintain their electrical properties under elevated temperatures. They are therefore of

particular value where any or all of these qualities are required.

The copper conductors, which may be single or stranded, are lapped with asbestos paper tape which, besides being fire resistant has a low rate of moisture absorption. With the current ratings adopted, the cables have a large overload capacity, the insulation being indestructible, and will continue functioning at temperatures up to the melting point of the sheath. The permanence of Pigebestal cable is generally similar to that of other types of aluminium sheathed cable, and is normally not very different from that of lead-sheathed cable. Additional protective covering is available and is essential where the cable is drawn through ducts, laid direct in the ground or liable to be exposed to corrosive atmospheres.

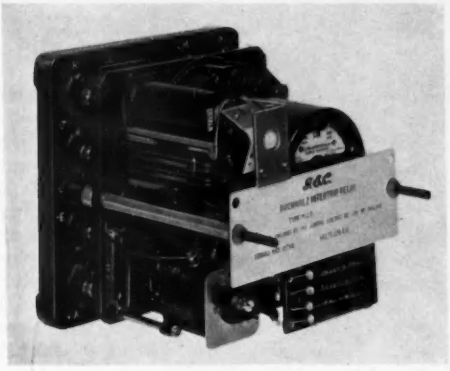

Fig. 11.—Surge-proof relay, type M.C.T.

Pigebesteel is suitable in situations where greater strength and resistance to mechanical damage are required. Its excellent corrosion resisting properties render it particularly valuable in such conditions as are encountered in chemical and rayon factories. In the matter of installation and jointing it should be noted that non-plumbing type terminating glands are available and that, for indoor situations, no sealing of the glands is needed on account of the high resistance of the insulant to absorption of moisture.

Mercury Arc Rectifiers.

More than eighteen years' experience with G.E.C. pumpless rectifiers has shown the merits of the side arm construction from the point of view of design, manufacture and operation. This form of construction has proved particularly valuable with grid-controlled rectifiers of the standard multi-anode types, and the Company has now developed the first single-anode grid-controlled air-cooled pumpless rectifier embodying the side arm principle. Fig. 12 shows the new rectifier which is provided with continuous excitation and grid control. It can be used on any of the standard rectifier circuits, but is especially suitable for three-phase, full wave rectification which, from a three-phase supply, gives a smoothness equivalent to that of six-phase rectification. Where a supply is available at the proper voltage, the rectifier transformer can be omitted and a simple form of current limiting reactor substituted in each phase, the circuit arrangement being shown in fig. 13. Although this rectifier has been developed primarily to meet the requirements of special drives and is not intended to replace the standard multi-anode arrangement, it is anticipated that it will find other applications beyond its immediate purpose.

From the point of view of the multi-anode types, the past year may be described as one of consolidation of experience gained with the innovations introduced since the war. Several large new installations have been successfully commissioned and further large contracts, including several repeat orders, have been obtained. For example, in the field of heavy traction, the first group of 1,200 kW, 1,500 volt six-phase rectifiers, representing ten equipments out of the sixteen under construction, has been

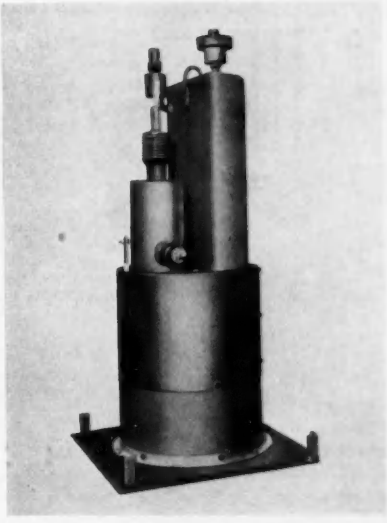

Fig. 12.—Single anode rectifier with air ducting removed

put into service with the Netherlands Railways. A feature of these rectifiers has been the incorporation of high-speed electronically applied arc suppression by grid control as a standard feature in all substations. Another interesting installation in Holland, commissioned this year, consists of three 1,200 kW, 610/580 volt rectifiers for the Rotterdam Tramways.

The adaptability of pumpless rectifiers in the sphere of traction is exemplified by two 1,000 kW 550/470 volt grid-controlled transportable equipments delivered to Buenos Aires on the order of Sofina. These equipments may be connected in series to give a 1,100 volt supply for street railways, or used separately at 550 volts for light traction or at 470 volts for industrial loading. A feature of these rectifiers was the limit imposed as regards the dimensions of the complete equipment in order to enable it to pass through some of the narrower streets in Buenos Aires, which necessitated each equipment being mounted on three separate vehicles. Nine 500 volt equipments totalling some 4,900 kW have also been supplied to Wellington City Council, New Zealand. Two of these are three-wire equipments for 250/250 volts, using twin cylinders as static balancers. New orders for traction rectifiers include forty-eight 2,500 kW, 750/660 volt equipments for the frequency changeover in the London area of the electrified system of £2,000,000, and it is interesting to note that when this work is complete, the total installed capacity of the Company's pumpless rectifiers on railways in this area will be 194,000 kW. Another particularly interesting order is that for three 1,000 kW, 630 volt equipments for the new Surrey Docks Substation of the London Transport Executive. For this contract the rectifier transformers will be of special design and air-cooled.

Traction work overseas is represented by an order for 1,200 kW 1,600 volt equipment for the Estoril Railway at Lisbon, further orders from Wellington City Council and a contract from Whitehall Securities, Ltd. for Athens Tramways totalling over 6,000 kW.

The Company continues to be active in the industrial application of multi-anode rectifiers both at home and overseas. Equipments for Hadfields, English Steel Corporation, Lancashire Steel Corporation and Stewarts and Lloyds amount in the aggregate to a capacity exceeding 10,000 kW. For the shipbuilding industry two 240 kW, 240 volt equipments have been supplied to Swan, Hunter & Wigham Richardson, Ltd.

Considerable development has been made in the precision control of grid-controlled rectifiers, as, for example, in the power units supplied to Head, Wrightson & Company for their drawbench equipments. These units include grid-

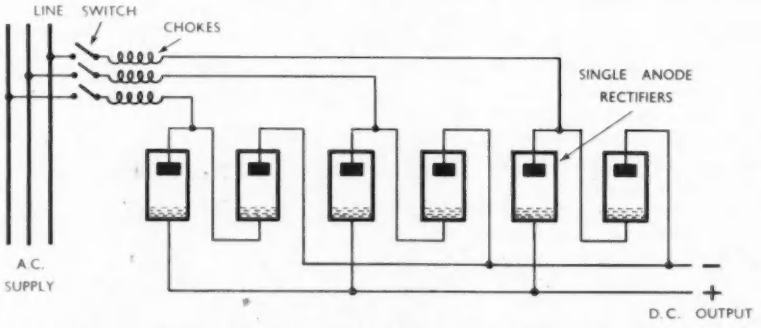

Fig. 13.—Diagram of connections of a six unit, single anode equipment fed directly from the supply and arranged for three-phase, full wave rectification. Grids and auxiliary circuits not shown.

the Southern Section of British Railways. These equipments, the transformers for which will be supplied from the Grid at 33 kV, 50 cycles, will be installed in 23 substations where they will replace existing converting machinery designed for a 25 cycle supply. The total value of this contract, which includes a large amount of 33 kV metalclad switchgear, exceeds

controlled rectifiers for two 100,000 lb. and three 25,000 lb. drawbenches ; further orders totalling 2,000 kW are in hand.

From Metal Manufacturers Ltd., Port Kembla, New South Wales, there is an order for complete electrical equipment for a 100,000 lb. drawbench, including a 500 h.p. 550 volt, 450/900 r.p.m. D.C. motor, a 410 kW, 550 volt grid-controlled

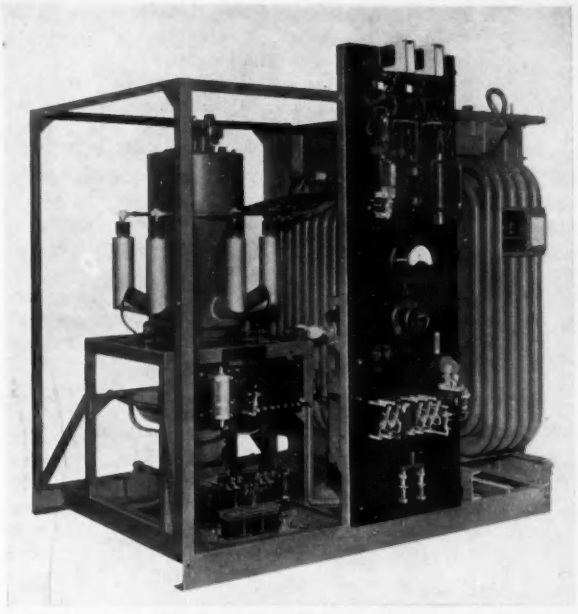

Fig. 14.—200 kW, 400 volt, 500 amp. D.C. unit type rectifier to be installed in Buckingham Palace.

rectifier equipment, a control board and two control desks. Another example is the 190 kW, 460 volt high precision electronic grid-controlled rectifier equipment for controlling a variable speed alternator set ordered by Chance Bros. Grid control regulating equipment has also been supplied in connection with a conversion to grid-controlled rectification for a 1,000 kW, 500 volt power unit for a wind tunnel at the College of Aeronautics.

A number of interesting smaller units are on order : a 60 kW rectifier for the Rand Mines, being a repeat of an earlier unit supplied in 1936 ; two-unit construction equipments of 200 kW each for Calico Printers Association Ltd., also in South Africa. India is represented by a 150 kW, 460 volt equipment for New India Assurance Co. Ltd., a 500 kW, 460/520 volt 3-wire equipment for New Delhi and four 250 kW, 480/240 volt, 3-wire, 3-cylinder static balancer equipments for Benares Hindu University. For the Hong Kong Electric Supply Company a 400 kW, 525 volt rectifier equipment is on order.

Finally, the Company takes pride in recording that it has had the distinction of receiving an order for the 200 kW, 400 volt, 3-wire rectifier equipment, together with a rotary balancer and control gear, for Buckingham Palace (fig. 14).

MINING GEAR.

From the North Eastern Division of the National Coal Board there is an order for the conversion to electric drive of an existing steam winder at Chanters Colliery, Manchester. The geared A.C. system will be employed, the motor being an 875 h.p., 2·2 kV, 485 r.p.m. slipring induction machine. When converted to electric operation, the winder will raise 3 tons of coal per wind from a depth of 1,466 ft.

For Bold Colliery in the North Western Division of the N.C.B. a contract has been accepted for the mechanical equipment for three electric winders. Two of these will be geared drum winders with 15 ft. diameter single parallel drums, one designed to raise 4½ tons per wind from a depth of 1,833 ft., the other to raise and lower men from a depth of 2,750 ft. The third will be a geared electric Koepe winder with a wheel diameter of 26 ft. capable of raising 12 tons per wind from a depth of 2,745 ft.

At Nantgarw Colliery in the South Western

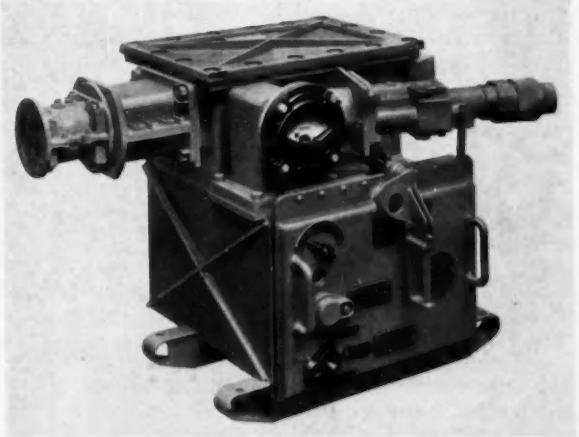

Fig. 15.—New design of flameproof gate-end box.

Division of the N.C.B. the South Pit winder which up to the present has been fitted with a sinking drum has now been modified and changed to a bi-cylindro-conical drum 12 ft. to 17 ft. in diameter. This winder will now handle the main coal output from the colliery.

With the increasing use of Koepe winders in this country, it has been deemed advisable to examine the existing equipment with a view to initiating some desirable improvements. Among recent developments has been a suitable braking system, careful consideration being given to the problem of rope slip when braking. The design of the wheel itself is also receiving attention.

A variety of mining equipment is being supplied to the Dominions. For G. A. Brown and Abermain Seaham Collieries Ltd., New South Wales, eight motor-generator sets are on order. Seven are rated at 60 kW each and will be used for in-bye working, the 250/275 volt D.C. output supplying trolley wire shuttle cars. The remaining set is rated at 400 kW and will provide a similar D.C. supply for trolley wire locomotives. The order also includes a number of motors.

On the Rand Mines, South Africa, the mechanical equipment for a geared double drum winder has been delivered and the winder is now in course of erection.

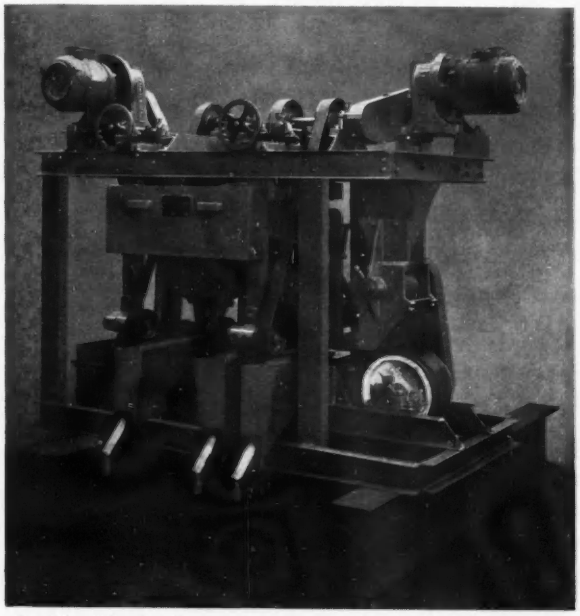

Fig. 16.—Weatherill magnetic separator for the Uganda Electricity Board.

GATE-END BOX.

A new design of gate-end box, conforming to the specification issued by the National Coal Board, is now in course of development (fig. 15). This is a size 1 box for the direct-to-line starting of coal cutter and conveyor motors at the coal face. The specification requires that the unit shall not exceed 26 ins. in height and 3½ cwt. in weight and shall be suitable for operating from a three-phase supply at voltages from 400 to 650 with a current rating of 80 amps. The top compartment of the box houses three busbars of 300 amp. rating fed by cable boxes from either end. An isolator, designed to break the load current, is mounted in this compartment. Units are arranged to bolt together to form a gate-end switchboard controlling several motors. The position and dimensions of the coupling flange are standardised so that the boxes of different manufacturers can be bolted together.

The lower compartment contains the contactor, overload relays, voltage transformer for the control circuit, the control relay, earth leakage relay and various control switches. The equipment in the lower compartment is built on a chassis which can be completely withdrawn without unbolting connections. The control circuit operates at 7·5 volts and meets the requirements of the Safety in Mines Research Board. The earth-leakage circuit is operated from a core balance transformer and is set to trip at about 1·5 amps. earth-leakage current. The front cover has a single bolt fixing giving rapid access to the interior for maintenance. The contactor has been tested for breaking capacity up to 1,400 amps. at 650 volts and 100 operations at 5 second intervals at 650 volts, 650 amps. The tests were made with the unit completely bolted up.

This is the first of a series of units being developed and so designed as to line up together and form a switchboard. Other units in course of development are a size 2 box, 150 amp. rating, a drill panel, a lighting panel and a circuit breaker section switch.

MAGNETIC SEPARATOR.

There has recently been constructed at the Erith Works a Wetherill magnetic separator of

the laboratory type for the Uganda Electricity Board at Kampala (fig. 16), which will be used for examining a range of feebly magnetic minerals. The separator is of the single magnet type with two poles and an auxiliary pole, it is equipped with a roll feeder, the necessary feed hopper, discharge chutes and three cross belts. The main belt, which is 7 ins. wide, is driven by a ½ h.p. back-geared motor, cone pulleys permitting it to be run at three different speeds. Another ½ h.p. back-geared motor operates the cross belts. A special belt tapping gear is fitted to turn the material over as it passes between the poles. A control board is provided for adjusting the magnetising current, also a voltage regulator, resistances and rectifier. A hand-operated gear permits variation in the gap between the upper and lower poles.

Copper-Nickel Converter.

An interesting order recently completed and shipped by the Erith Works is a copper converter for the Rustenburg Platinum Mines Ltd., South Africa. The converter is a duplicate of one forming part of a complete smelting plant supplied in 1937 for the smelting of copper-nickel concentrates and producing about 100 tons of copper-nickel in a 20-day campaign, working 20 hours a day. The plant is situated at an altitude of about 4,500 feet above sea level in the Rustenburg area of the Transvaal. These converters are of the vertical type ; one, just completed, is seen in fig. 17. The converters are power operated by 15 h.p. motors of the totally enclosed type running at 712 r.p.m. and designed for an A.C. supply of 500 volts, three-phase, 50 cycles. The driving motor of the first machine was controlled by a drum-type controller provided with creeping or inching contacts. For the new converter a contactor control panel has been specially designed embodying two master control stations, to give local and remote control, and enables the converter to be traversed forward, reversed, inched forward and inched in reverse. For forward or reverse travel, the motor would normally run until the stop button is pressed or the circuit is tripped by a limit switch on an over-travel.

The travel of the converter is from the nearly vertical charging position to the pouring position slightly below horizontal, a total of some 105°, depending largely on the contents of the converter. The most important operation is that of pouring which is performed slowly at about 5 ft. a minute with the motor running at its lowest speed, as great care is necessary when slagging off to ensure that no metal is lost. The local control panel carries an emergency stop button and a control handle for starting and turning the converter ; the remote control panel has a station selector switch and backing out control for use when the limit switches have been tripped, also a control handle for inching the converter when pouring. There is, in addition, an emergency stop switch.

A second control cabinet has been supplied to enable the original converter to be operated under the new system. All the electrical gear, which has been treated to withstand the fumes given off during the converting process, is enclosed in dust-proof cases.

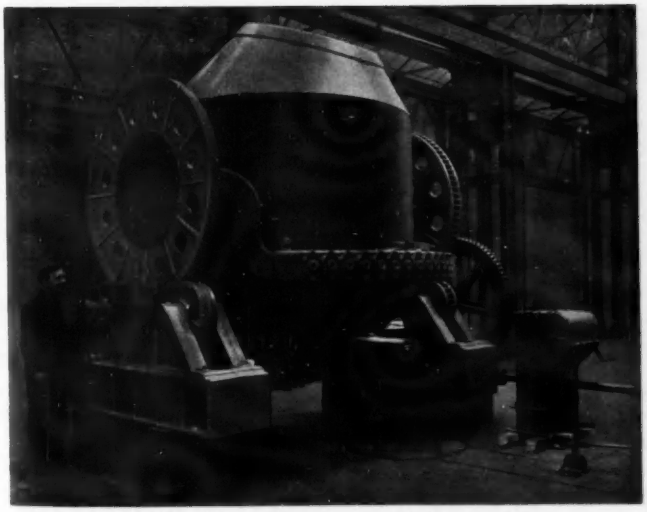

Fig. 17.—Vertical type copper-nickel converter.

HAMMER MILLS FOR COAL CRUSHING.

An interesting export order, in course of execution at the Company's Erith Works, comprises a series of Pennsylvania hammer mills for crushing coal for the boiler plant of the Electricity Supply Commission of South Africa. Four of these mills have been shipped, two are ready for dispatch and two more are in course of manufacture. The first machines supplied were fitted with ordinary Pennsylvania hammers which were found to give too fine a product because certain of the South African coals are so friable that, when crushed with the normal type of hammer, the product contained so many fines that it was unsuitable for use in the new boiler plant. Trials showed that the Pennsylvania granulator, or ring type hammer mill, gave a product which fulfilled the requirements (fig. 18). Some of the original machines were converted from the standard type to the granulator type ; the last two machines in course of completion are designed entirely as granulators. These machines are built of steel with rotor shafts carrying the granulator rings which revolve inside the frame into which are fitted a fixed breaker plate and adjustable screen plates. The rotor of this type of machine is usually fitted with three or four rows of rings carried by dual suspension shafts. The effect of these shafts is to cause the rings to roll across the feed with positive pressure, cracking and battering the coal into granular pieces. Thus a more granular product results with a slower rotor speed, and enables the mill to be run at about 480 r.p.m. as against 960 r.p.m. required with a hammer mill. Consequently less fines are produced, less power is needed and there is less wear on moving parts.

Four of these mills are for the South Rand Colliery and two for the Cornelia Colliery. Each has a capacity of 350 short tons of coal an hour, the feed size being minus $3\frac{1}{2}$ ins. and downwards, while the product will be minus $\frac{3}{4}$ in. square mesh. The mills are driven through 2 : 1 reduction gearing by 340 h.p. A.C. motors running at 960 r.p.m.

The two remaining mills are for the Vierfontein Power Station. They have a capacity of 315 short tons an hour, the feed size of the coal being minus $3\frac{1}{2}$ ins. and the product minus $\frac{3}{4}$ ins. square mesh. The operating speed is again 480 r.p.m., the mills being driven by 300 h.p. motors running at 960 r.p.m. The motors are all arranged for direct-to-line starting and drive the mills through totally enclosed reduction

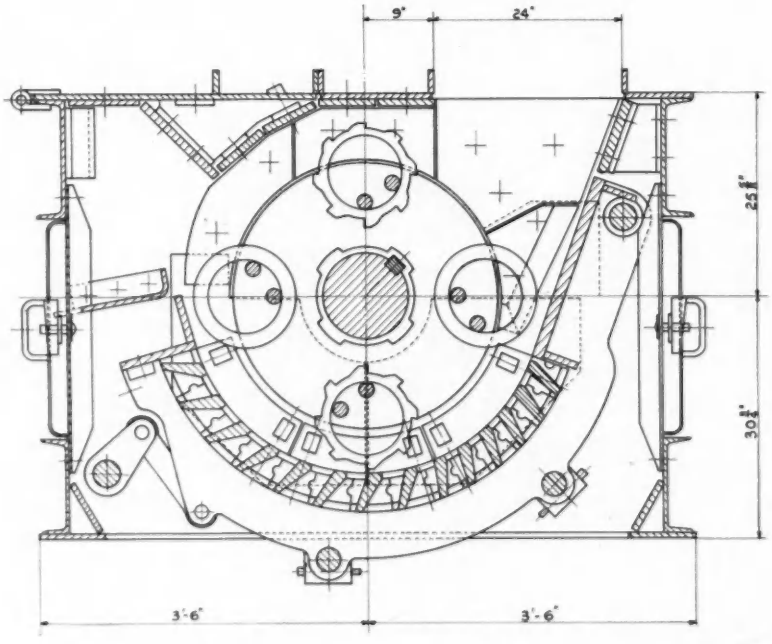

Fig. 18.—Section through a Pennsylvania granulator, or ring type hammer mill.

gears to which they are coupled by means of Vulcan-Sinclair fluid couplings. It is to be noted that the installation of the new machines has enabled several crushers to be dispensed with, one machine, in each case, sufficing to perform all the necessary crushing.

An entirely new system of coal firing, which will be the first installation of its kind in this country, is being introduced at the Barking Power Station of the British Electricity Authority. For this purpose three Pennsylvania hammer mills of a special type are being built to the order of Babcock & Wilcox, Ltd. They are to be used for coal crushing and their general construction is similar to the Pennsylvania reversible hammer mill, the special feature being that all openings are sealed as carefully as possible against the escape of air and dust. The casing is made especially tight and seals are fitted at the various openings. In particular, the sealing of the main shaft is accomplished by arranging for an annular space around the outer part of the rotor shaft bearing, and into this space is introduced air at a pressure slightly greater than that in the mill. Each of these hammer mills is capable of crushing 12 tons of coal an hour, the feed size being minus 2 ins. diameter ring and under, with 15 per cent moisture, and the product is to be as near No. 4 Tyler mesh screen as possible. The mills are driven through V ropes at 960 r.p.m. by 60 h.p. motors running at 1,470 r.p.m. The mills will be employed for a system of direct firing, one mill being required for each burner.

Coal Preparation Plant.

The Chance sand flotation process of cleaning coal has been long established and particulars of various installations have, from time to time, been recorded in this Journal. As an indication of its world-wide acceptance it may be noted that well over 40,000,000 tons of coal are cleaned annually by this method. As a result of recent experiments with the Chance sand flotation cone, equipment has been developed to give a middlings product as well as the more usual clean coal and refuse only. This equipment, which is known as a middlings column, is attached to the side of the cone, as shown in fig. 19, and the low-gravity zone in the cone, above the column outlet, is so controlled as to allow the middlings and refuse to sink to this level. The high gravity zone below the column is controlled in such a way as to allow only the refuse to sink through it, thus leaving the middlings to float in this zone and eventually to leave the cone by way of the middlings column. This equipment has recently been put into commercial use in a coal preparation plant in India with highly satisfactory results. Similar equipment is, in consequence, being included with four coal preparation plants now under construction and

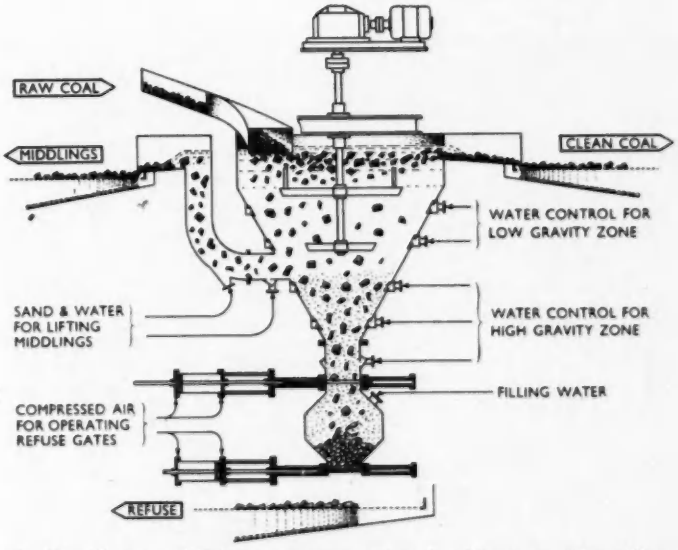

Fig. 19.—Chance sand flotation process : section of washing cone with middlings separator.

will undoubtedly become a standard feature in all future installations.

MECHANICAL HANDLING.

An operational problem with large coal handling bridges at power stations, and elsewhere, is the possibility of mis-alignment. That is, the axis of the bridge may cease to be at right angles to the direction of travel. This is brought about by the use of separate drives at each end of the bridge, the necessity for which will be appreciated when it is realised that these bridges may have a span of 200 ft. or more.

A solution to the problem of indicating and limiting this mis-alignment has recently been found in the use of repeater motors of the Magslip type. In this system an accurately machined recording wheel, mounted on a trailing arm, is attached to the bogie at each end of the bridge. These wheels, which run on low friction bearings, bear on the rails and are drawn along by the bridge. Thus the degree of rotation of the wheels provides an accurate indication of the distance travelled by each bogie. Geared to the wheel units are repeater motors which transmit impulses to an indicating unit mounted in the control cabin at the centre of the bridge. This unit is equipped with two Magslip elements : a " hunter " and a " follow-through transmitter". The first of these is fitted with a pointer, which moves over a dial calibrated in feet and inches. This dial has a central zero and shows the distance by which one bogie leads, or lags behind, the other. The action of the " hunter " is differential between the two bogie units, thus when the recording wheels move together through equal angles no movement of the " hunter " takes place. However, if there is a difference of angular rotation, it will be indicated by movement of the " hunter " rotor.

The " follow-through transmitter " is placed between one of the bogie units and the " hunter " and functions as a zeroing device. Under normal running conditions the rotor of this unit is clamped and plays no part in the operation of the device ; if, however, some slight amount of slip takes place between one recording wheel and the rail, due, for instance, to icy conditions, it is clear that there will be a slight error in the indicated mis-alignment. Under these conditions the bridge is moved to some fixed datum and lined up. The rotor of the " follow-through transmitter " is then rotated until the pointer on the " hunter " again registers zero, whereupon the normal operation of the equipment can be restarted. It is anticipated that the amount of slip will be very slight and re-zeroing necessary only at comparatively long intervals.

In order to keep the degree of mis-alignment within predetermined limits, the dial and pointer on the " hunter " are fitted with contacts. When these close, relays are operated which prevent any further movement of the bridge until the error has been corrected. Finally it

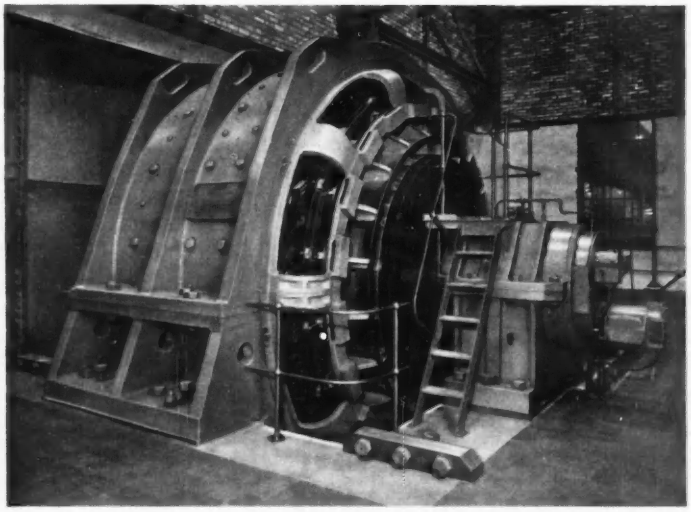

Fig. 20.—5,000 h.p. cogging mill motor at the Redbourn Works of Richard Thomas and Baldwins, Ltd.

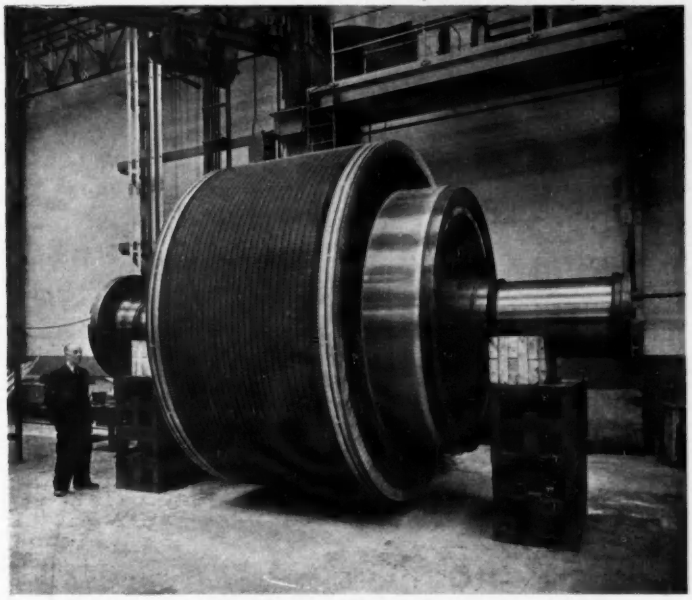

Fig. 21.—Armature of the 5,000 h.p. 700 volt cogging mill motor for Richard Thomas and Baldwins, Ltd., Redbourn.

should be added that a most satisfactory feature of the system is the absence of any mechanical connection between the bogies and control cabin, wiring running in conduits being all that is necessary.

ROLLING MILLS.

A comprehensive contract has been concluded with the Whitehead Iron and Steel Co. Ltd., Newport, for the electrical equipment for a cold strip mill. The stand motor is rated at 0/200/200 h.p. at 0/250/250 volts and the coiler motor at 0/150/150 h.p. at 0/350/350 volts, the speeds of both machines being 0/300/750 r.p.m. The main mill is Ward-Leonard controlled and cascade exciters are used for the control of the coiler motor. The contract also includes a 300 kW, 0/250 volt motor-generator set, a 37 kW booster and a 20 kW bucking generator driven by a 70 h.p., 500 volt squirrel cage motor; a 50 kW drag generator and a ten-panel 6 kV, 350 MVA metalclad switchboard, together with the transformers and reactors mentioned earlier under that heading.

The conversion of the 40-inch cogging mill at the Redbourn Works of Richard Thomas and Baldwins, Ltd., from steam to electric drive has been completed, and the mill is now in operation. It is driven by a 5,000 h.p. 0/50/100 r.p.m., 700 volt D.C. motor (12,500 peak horsepower) arranged for Ward-Leonard control with cascade exciters, which, owing to the size of the main machines, are of the 3-stage design. Provision is made for dynamic braking of the Ward-Leonard Ilgner set, and the 100/200 h.p. screw-down motors are also controlled on the cascade exciter system. The main mill motor is seen in fig. 20 and a shop view of the armature in fig. 21.

Fig. 22.—The last roughing stand of the hot strip mill in the Abbey Works of the Steel Company of Wales.

The 45-inch slabbing mill and the continuous hot strip mill at the Abbey Works of the Steel Company of Wales are now in commission and the coil and sheet skin pass mills are nearing completion. At the Tinplate Works at Trostre the pickling line is now running and the No. 1 temper mill is expected to be completed early in 1952. The last roughing stand of the hot strip mill at the Abbey Works is seen in fig. 22 ; the 75 h.p. mill-type motor seen in the foreground operates the delay cable. Further orders received from the Steel Company of Wales include one for 100 totally enclosed 415 volt squirrel cage motors ranging from 5 h.p. to 58 h.p. and totalling over 1,400 h.p., for use in an ore preparation and sinter plant at the Margam Works.

A single stand, reversing cold rolling, steel strip mill supplied by W. H. Robertson, Ltd., of Bedford, to Devillez et Camion is now in commission at Paliseul, Belgium. For this contract the Company has provided the main and auxiliary mill motors, the motor generator set, A.C. and D.C. switchgear and the control desk. The contactor control board for this mill is seen in fig. 23. The main mill motor is rated at 0/375/375 h.p., 0/300/300 volts, 0/500/1,000 r.p.m., and the two coiler motors at 0/37·5/75/75 h.p., 0/240/480/480 volts, 0/275/550/1,370 r.p.m.

The two screwdown motors are high torque squirrel cage machines rated 7½ h.p. at 960 r.p.m. The motor-generator set is driven by a 600 h.p. 380 volt slipring motor running at 960 r.p.m.

A further export order is that received from the Loewy Engineering Co., Ltd., for the electrical equipment for a cold strip mill which they are supplying to Austral Bronze, Ltd., Australia. The equipment includes a main motor-generator set with an 1,130 h.p., 5 kV, 986 r.p.m. slipring driving motor ; an auxiliary motor-generator ; the 850 h.p. main mill motor, 0/500 volts, 0/500 r.p.m., a 150 h.p. reeler motor, a 100 h.p. up-coiler motor, together with all associated switchgear and motor control gear. Cascade exciter control is employed with the reeler and up-coiler motors.

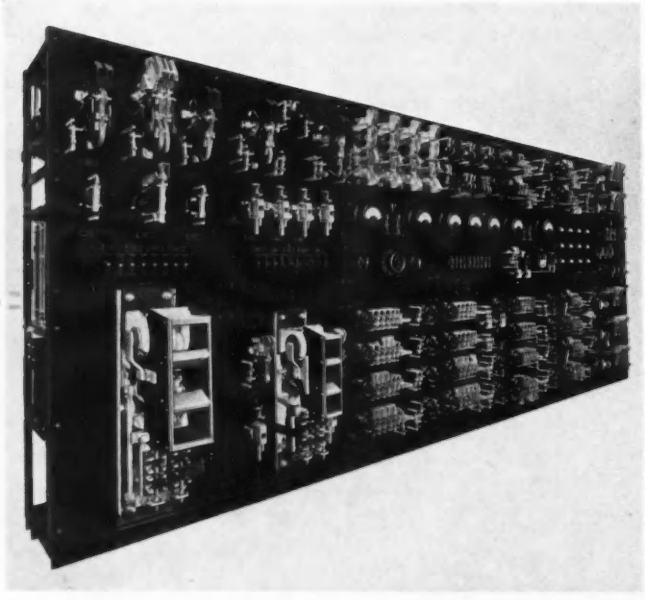

Fig. 23.—Circuit breaker and contactor control board for the 250 h.p., single stand, reversing cold rolling, steel strip mill for Devillez et Camion, Belgium.

INDUSTRIAL ELECTRIFICATION.

Oil Industry.

During the course of the year a number of orders has been received from the Shell Petroleum Co., Ltd., for motors to drive oil well pumps. These will, in all cases, be squirrel cage machines designed to operate at a speed of 875 r.p.m. from a 60 cycle A.C. supply. The number of motors at present on order is 179, aggregating 11,500 h.p.

For the Associated Ethyl Co., Ltd., a large contract for motor control gear is in course of execution. The equipment to be supplied includes thirty-five switchboards with on-load isolators and direct-to-line contactor starters mounted in two- and four-tier form in sheet steel cubicles. The switchboards are to be installed in two new works for the production of lead tetraethyl. Arrangements are incorporated for the sequence control of all the motors driving pumps, conveyors and the like.

Dustproof Solenoids.

A.C. solenoids are used for a large variety of industrial purposes both with local and remote control. When installed in dusty

situations such as gasworks and collieries, solenoids are liable to suffer rapid wear of the moving parts and to be contaminated internally by the ingress of abrasive dust. Entry of dust normally occurs in both the dashpot and in the main body of the solenoid when the unit

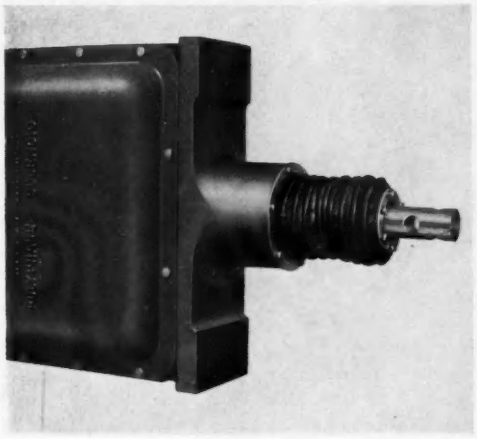

Fig. 24.—Industrial type of dustproof solenoid.

is de-energised, due to displacement of air by the dashpot and the solenoid plunger. Under these conditions the internal air tends to fall below atmospheric pressure, and in consequence external air enters. To avoid this, therefore, a modified design of solenoid has been introduced in which the plunger is sealed by a leather bellows (fig. 24). Air transfer passages are so arranged that only an internal interchange of displaced air takes place, thereby avoiding the introduction of external air and any impurities which might be carried in with it.

Deep-Penetration Magnet.

A deep-penetration magnet has been produced for handling scrap which has to be lifted from, or placed into, restricted spaces such as railway trucks. Maximum lifting capacity with minimum diameter of magnet has been achieved by increasing the ratio of overall depth to diameter, thereby improving the penetration of the external field. In the magnet shown in fig. 25 the diameter is 56 ins., the weight 5 tons and the rating 15 kW. The performance is approximately equal to that of a standard 64 in. diameter magnet.

Magnet Applications.

A number of orders has been received from overseas for lifting magnets, magnetic brakes and kindred equipment. Eleven lifting magnets, ranging in size from 43 ins. to 64 ins., and 18 magnetic brakes are in hand for Canada ; 14 magnetic brakes are in course of construction for Johannesburg ; a 64-in. suspension type separator magnet has been ordered for the Mufulira Copper Mines, Northern Rhodesia, and a 3-ton hoist block for Titaghur Paper Mills, Calcutta.

Textile Electrification

During the year the range of loom motors for the textile industry has been extended by the addition of machines developing ¾, 1, 1¼ and 1½ h.p. at 720 r.p.m. on a 50 cycle A.C. supply.

Of the export orders at present in hand for electrical equipment for textile use, one of the more important is that for the complete electrification of the Khaipur State Textile Mills, Pakistan, which includes 500-¾ h.p. loom motors with automatic starters and pilot switches. A contract from Khan Bahadur H. M. Habibullah & Co., Ltd., Karachi, covers 116 squirrel cage motors ranging from ½ h.p. to 12 h.p., together with starters. For the Raja Bahadur Motilal Poona Mills, Ltd., Bombay, 12-40 h.p., 400/440 volt totally enclosed, fan cooled, squirrel

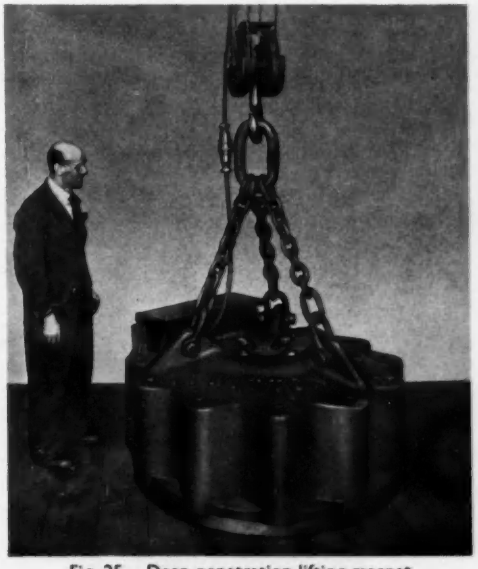

Fig. 25.—Deep-penetration lifting magnet.

cage motors are on order for driving line shafting.

Grain Elevators.

Mention has been made in earlier Progress Articles in this Journal*of the electrification of the New Port grain elevator in Buenos Aires. With a total capacity of 150,000 tons it is the largest of its kind in the Southern Hemisphere. This installation has now been completed and handed over to the Argentine Government. An official inauguration by the Minister of Works, General Pistarini, marked the occasion of its being put into service. The main contractors were Simon Handling Engineers, Ltd., of Cheadle Heath, Stockport ; the whole of the electrical equipment comprising motors, transformers, switchgear, control boards, lighting and telephones, was supplied by the G.E.C.

* *G.E.C. Journal*, Vol. XVII, No. 1, Vol. XVIII, No. 1, January 1950 and 1951.

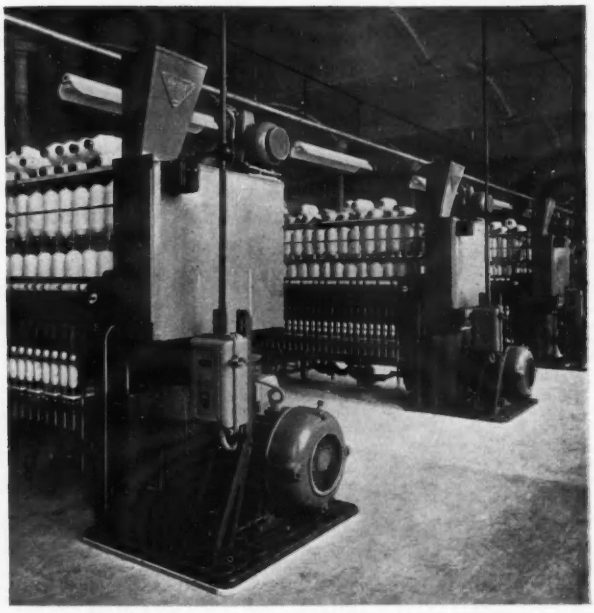

Fig. 26.—10 h.p., 400 volt, 1,440 r.p.m. cowl cooled motors driving ring spinning frames at the Brook Mill of Oldham Twist Co., Ltd., Hollinwood, Lancs.

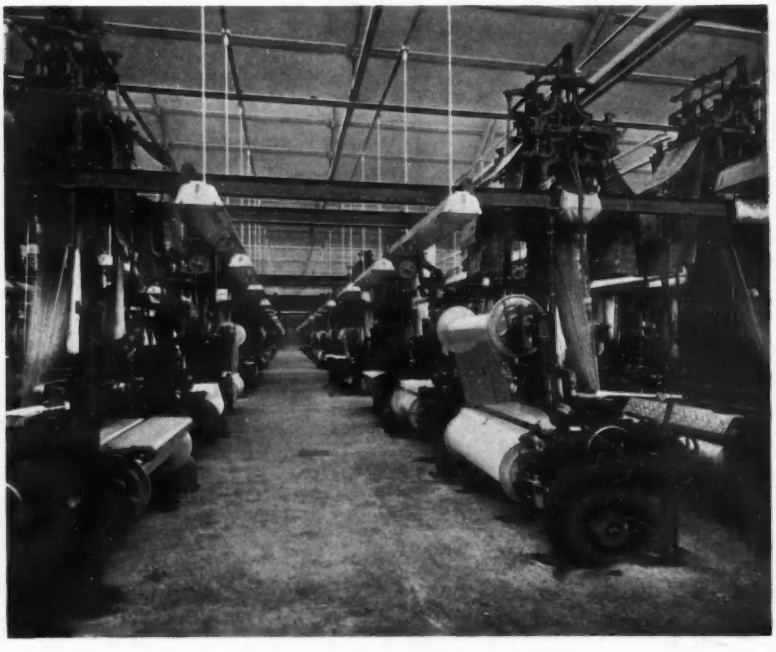

Fig. 27 (*below*).—An aisle in a Lancashire mill showing Jacquard looms driven by 1 h.p., 960 r.p.m. loom motors. Lighting is by means of fluorescent lamps, the reflectors having an aperture above the lamp to permit upward illumination.

TRANSPORT.

Railway Electrification.

A full description of the electric traction equipment supplied to Sociedade Estoril, Portugal, was published in the *G.E.C. Journal* in April, 1951. It is of interest to record that a further order for nine motor coaches, four driving trailers and one trailer coach has been received. Apart from a few minor changes based on running experience, and to meet slightly different requirements of the railway company, the equipments are identical with those previously supplied, although driving trailers are now included in the order.

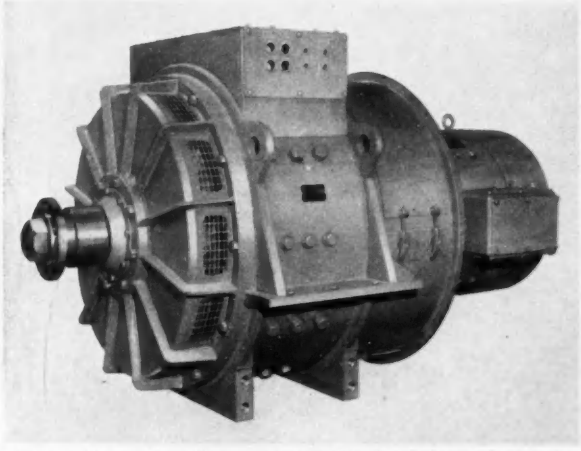

Fig. 28.—Main and auxiliary generators for diesel-electric locomotive for Ceylon Government Railways.

During the year eight diesel-electric locomotives have been completed for the Ceylon Government Railways and most of them are already in service. These locomotives are of the 2-bogie, 4-axle type, each weighing 54 tons and designed for use on a 5 ft. 6 in. track. They will be employed for general yard shunting at Colombo and elsewhere, as well as for hauling goods trains on branch lines.

The main generator (fig. 28) is driven by a 625 h.p. Paxman diesel engine and suplies power to the four traction motors. For the handling and starting of the trains, various outputs of the engine up to a maximum are obtained by the remote setting of the governor by electro-pneumatic means under control of the driver through his master controller. An oil-operated servo motor, controlled from a pilot valve directly associated with the engine governor, operates a rheostat in series with the main field of the generator. The action is such that constant power is obtained over the whole range at any speed setting, yet the engine cannot be overloaded. A view of one of these locomotives is seen in fig. 29.

The forty 3,000 volt, 3,000 h.p. main line locomotives on order for the South African Railways and Harbour Administration are now in course of erection and a considerable amount of equipment has already been delivered to the

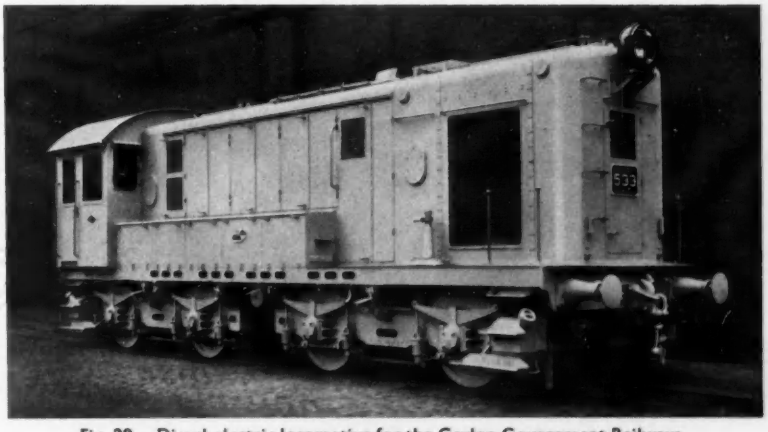

Fig. 29.—Diesel-electric locomotive for the Ceylon Government Railways.

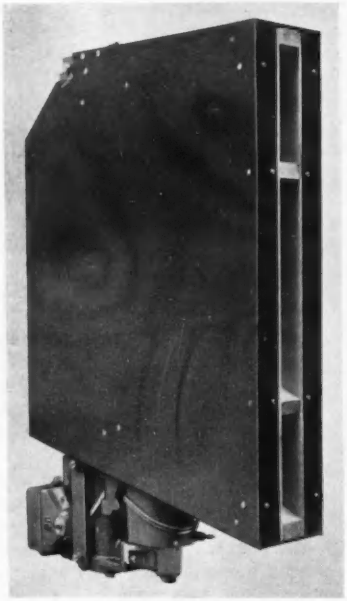

Fig. 30.—3,000 volt contactor, with arc chute in position, for the South African Railways.

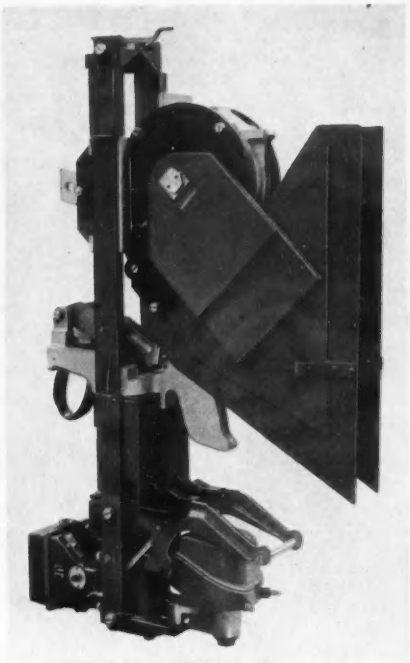

Fig. 31.—The 3,000 volt contactor shown in fig. 30 with the arc chute removed.

engine builders. Figs 30 and 31 show the 3,000 volt contactor with the arc chute on and off respectively. This contactor is designed to have a liberal continuous rating at 300 amps. and to operate up to 4,000 volts. It must be capable of breaking 4,000 amps. at 3,300 volts and 12 milli-henries, and lower current values up to 4,000 volts and 25 milli-henries. The production model for the South African Railways has passed the various tests with an ample margin. The contactor is of the pneumatic type operated by an air piston under the control of an electro-pneumatic valve.

Another piece of equipment which is of interest is the heavy duty camshaft switch seen in fig. 32. These cam groups in various forms are used for reversing the main motors and for changing connections from motoring to regeneration. The cams are of high-grade insulation material and the contact elements are cam-opened and spring-closed. They are also provided with the usual knuckling spring in order to provide the proper tipping and rubbing of the contacts when closing.

The auxiliary contacts, shown on the left-hand side, are of a silver-tipped butt type, cam-operated. They are enclosed in a dust-tight case and experience indicates that they should operate for some years without attention. Fig. 33 shows the master controller. The handle arrangement has been

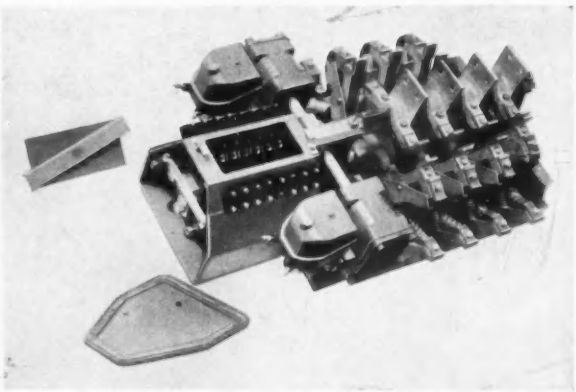

Fig. 32.—Heavy duty camshaft switch for the South African Railways.

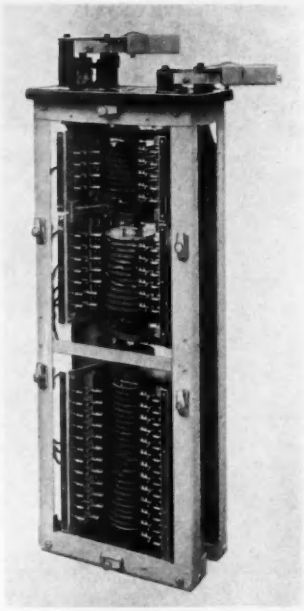

Fig. 33.—Regenerative locomotive master controller for the South African Railways.

designed to the Railway's general requirements but the actual contacts are all cam-operated, butt type, silver-tipped, and arrangements are made for dust-tight enclosure. A controller with similar contacts has been in operation for two years without being adjusted or touched in any way. The controller in question was used on trolley bus equipment, operating some 1,500,000 times in two years without appreciable wear or mechanical trouble.

As noted in an earlier review of progress in the *G.E.C. Journal*, the Company supplied the electrical equipment for six heavy duty battery-operated locomotives for the London Transport Executive—at that time the London Passenger Transport Board—shortly before the war. A subsequent order for seven additional equipments has now been completed and some of the locomotives are already in service. As an indication of the size of these locomotives it may be noted that the battery has a capacity of 1,008 ampere-hours at the five-hour rate and that there are 160 cells per locomotive. An illustration of one of these locomotives is shown in fig. 34. Their use is mainly in connection with new construction, cable laying, track maintenance and, in rare instances, with accidents.

During the course of the year further batches of traction motors have been supplied to the L.T.E. for use with both tube and surface line rolling stock.

Trolley Buses.

Deliveries have been made of trolley bus equipment for Cardiff, and Hobart, Tasmania. For about a year an experimental equipment with an improved form of rheostatic brake

Fig. 34.—Heavy duty battery-line locomotive for London Transport Executive.

has been running very successfully on the system of the Reading Corporation. This equipment which embodies what is virtually a series motor has an additional shunt winding which operates in a somewhat unusual way. The new arrangement not only gives a rather more suitable shape of braking curve, since the braking effort is maintained almost to standstill, but also results in the copper in the motors being used more efficiently. This has made possible certain improvements in motor design.

One of the most notable developments of recent times is the very wide adoption of the use of alternating current for engine room auxiliaries and other duties in merchant ships, particularly in tankers. From the Eagle Oil & Shipping Co., Ltd. and the Anglo-Saxon Petroleum Co., Ltd., orders have been received for the electrical equipment for twelve tankers. Each equipment includes two 550 kW, 440 volt, three-phase alternators to be turbine driven at 1,200 r.p.m., one 200 kW alternator to be diesel driven at 600 r.p.m. and about 25 motors ranging from 1·5 h.p. to 178 h.p. for pumps, fans, steering gear and other duties. The switchgear comprises a steel cubicle type main switchboard, with withdrawable air break circuit breakers, for controlling the generators, power supply, lighting and auxiliary services ; also two cubicle type group starter switchboards for controlling the motors. For three of these ships the Company is supplying complete geared turbo-alternator sets.

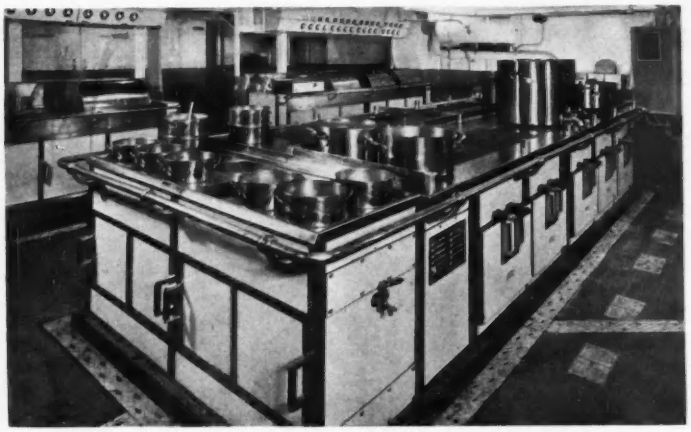

Fig. 35.—Cooking equipment in the main galley of the " Ocean Monarch."

A further repeat order for 24 trolley bus equipments has been received from the Belfast Corporation Transport Department. While generally similar to those previously supplied, they will embody motors of greater horsepower, automatic acceleration and butt contact type master controllers.

It is of interest to record that a modern trolley bus has been sent to Spain for demonstration purposes with the Empresa Municipal de Transportes in Madrid.

MARINE ELECTRICAL EQUIPMENT.

From the Director of Navy Contracts an order has been received for eight 155 kW, 225 volt, 1,250 r.p.m. turbo-driven, totally enclosed, water-cooled D.C. generators. Thirty-five generators of a similar type, but designed for oil engine drive, are on order for Davey, Paxman & Co. Ltd. These, also, are for Admiralty service and are rated at 150 kW, 225 volts.

A contract for electrical equipment for the Karachi Graving Dock has been concluded with Gwynnes Pumps, Ltd., and includes vertical spindle motors, totally enclosed squirrel cage motors, together with switch and control gear.

Similar geared turbo-alternators are being provided for tankers for the Gulf Oil Corporation and a number of 350 kW D.C. sets are in hand for several tankers for various owners as well as four 750 kW turbo-generators for an Admiralty hospital ship.

The diesel-electric pilot vessel " Sir Thomas Brocklebank ", built by Phillip & Son, Dartmouth, for the Mersey Docks and Harbour Board, was commissioned in October, 1950 and it is to be noted that an order has now been received for the complete electrical equipment for a similar vessel.

For the Booth Steamship Company, Ltd., an order has been completed for the electrical

equipment for a passenger and cargo steamship. In this instance the equipment includes three 200 kW diesel-driven generators, a 40 kW auxiliary generator, approximately fifty motors ranging from 1 h.p. to 73 h.p. for auxiliary drives, and ten automatic starters for controlling the larger auxiliaries.

which is 25 ft. long and incorporates over 178 ft. of gold and white cold cathode tubing, forming the largest single fitting of this type afloat. The cabin fittings are executed in Roanoid and are also of original design.

Another interesting scheme of cold cathode lighting installed in the " Vera Cruz " of the

Fig. 36.—Illumination of the Coral Cafe in the " Ocean Monarch ".

For the Blue Star Line an order has been received for the electrical equipment for a refrigerated cargo ship. This vessel will be similar to the " Adelaide Star " and is the eleventh of the Blue Star Line's post-war ships to be fitted with electrical equipment manufactured by the Company.

Early in 1951 the turbo-electric passenger ship, " New Australia " formerly the " Monarch of Bermuda ", sailed on her first voyage on the Australian run. This vessel is being managed by Shaw Savill & Albion, Ltd., on behalf of the Ministry of Transport and, after the war, the whole of her electrical equipment was completely reconditioned by the Company.

Following the lighting of the " Rangitoto " and " Rangitane " of the New Zealand Shipping Co., Ltd., a contract for the cold cathode and tungsten lighting in the public rooms and cabins of the " Ruahine " has recently been completed. A judicious choice of cold cathode and tungsten has also been employed in the dining saloon, and some twenty-three special designs of tungsten fittings have been executed for use in the public rooms and entrances. Of particular interest is the fitting in "A" deck stairhall,

Nacional de Navegaçao Cia, comprises, in general, a combination of one gold tube and one ivory tube, mostly in the form of indirect illumination, for the majority of the first and second-class public rooms. In all, it is estimated that more than half a mile of tubing will be used.

Electrical equipment on an extensive scale has been supplied to the new Furness Withy luxury liner " Ocean Monarch ", plying between New York and Bermuda. For this quadruple-screw vessel of 13,000 tons, built by Vickers-Armstrongs Ltd., the Company has provided lighting in the public rooms, sound equipment, the entire cooking equipment in the main and crew's galleys (fig. 35), the telephone system, passenger lifts, cabin fans, a luminous call and fire alarm installation, plural starting equipment for engine room and auxiliary motors, and two 35 h.p. steering gear motors. In the public rooms, a pleasing blend of cold cathode fluorescent tubing and tungsten lighting is used, gold and warm white being the chief fluorescent colours. In all, more than half a mile of fluorescent tubing has been employed throughout the ship and the number of fittings exceeds 2,500, those in the public rooms and cabins being of

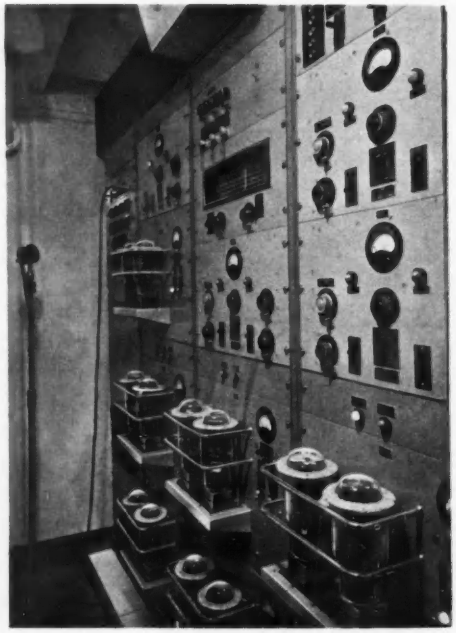

Fig. 37.—Main amplifier racks of the sound equipment system on the " Ocean Monarch ".

special design executed in silver-bronze. The lighting of the Coral Café (fig. 36) includes an attractive scheme of colour-changing and dimming.

The sound equipment system is believed to be the most extensive yet installed in any passenger vessel (fig. 37). A network of some 120 loudspeakers is distributed throughout the public rooms, promenade decks, officers' and crews' quarters and engine room. The captain and purser are given absolute priority over all other users, with automatic volume restoration on all speakers, whether working at reduced volume or switched off. Normally there is a choice of three programmes; radio, orchestra or gramophone records. Microphones are available in close proximity to the captain's table, on the bandstand, the sports deck and in all the public rooms large enough for concerts, dances, cinema shows and so forth. Power for the sound equipment is provided at 230 volts A.C. from a motor-generator set which also supplies the lighting. For emergency use a separate 5 kW, 50 cycle, rotary converter is available.

The continued popularity of the Company's system of plural starting is evidenced by the number of orders received from new clients as well as from old clients who have proved its value. Two notable ships on which plural starting equipment is installed have been put into service during the year: they are the " Singapore " of the P. and O. Steam Navigation Co., Ltd. and the " Ocean Monarch ". Since the commissioning of these two vessels, further orders have been received from the P. and O. Steam Navigation Co., Ltd. for plural starting gear for four ships similar to the " Singapore ", and for two large passenger vessels. The Blue Star line also has maintained its policy in specifying G.E.C. plural starting gear for their latest ship.

One of the best testimonials to the proven value of this type of equipment is the fact that the Furness Withy Company's vessel, " Monarch of Bermuda ", built over twenty years ago, was one of the first ships to use this form of starting gear and that, after this lapse of time, similar equipment has been unhesitatingly specified for this company's newest ship.

A particularly interesting order has been completed for John Cockerill & Company, Antwerp, for the " Vera Cruz ". In this case, plural

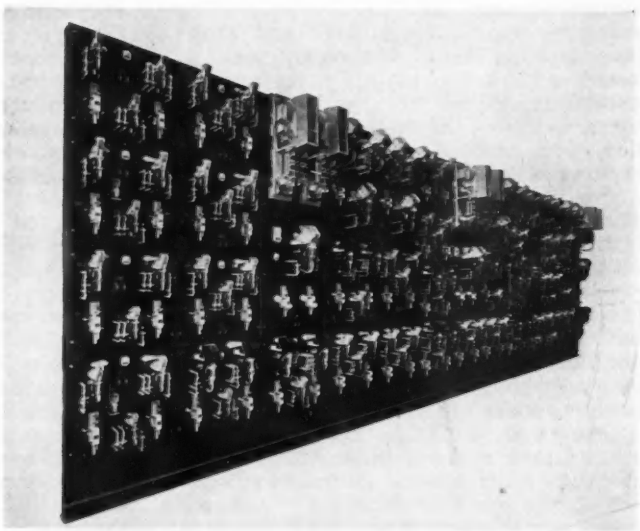

Fig. 38.—Plural starting board for the " Vera Cruz ".

starting equipment is required for controlling forty motors ranging from 12½ to 258 h.p. (fig. 38). Three common starters are being supplied, two to be in constant use in two groups of motors, the third being a standby. This will be the largest plural starting board ever built by the Company, and it is therefore pleasing to record that a repeat order has since been received for the sister ship, the " Santa Maria ".

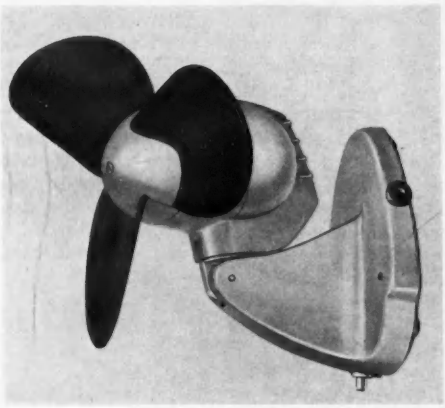

Fig. 39.—Wall bracket model of the new 10-inch, oscillating, rubber bladed fan.

Numerous orders have been received for galley gear, the most interesting being one from Vickers Armstrongs Ltd. for use in a bulk ore carrying vessel. The equipment is to be suitable for operation from a 440 volt, three-phase A.C. supply, and it is believed that this is the first merchant ship to be fitted with galley gear at this voltage. It is hoped that this is a forerunner of similar equipment, now that A.C. is being widely adopted for ships auxiliaries. Watts Watts & Co., Ltd. has placed repeat orders for galley gear for three ships similar to the " Wanstead ". Mention has already been made of the " Ocean Monarch ", and it is to be noted that she carries a fine example of the Company's galley equipment, all of which is finished in vitreous enamel and stainless steel ; the main range comprises ten ovens.

Automatic and manual telephone equipment is on order for two large passenger vessels now being constructed for the P. and O. A new type of ship's telephone has been developed and these instruments will be supplied with both installations.

ELECTRIC MOTOR DEVELOPMENTS.

FANS.

The 8-inch rubber bladed table and bracket fan described in this Journal in January, 1950, was produced in very large numbers throughout 1950-1951 and is now to be followed by a 10-inch oscillating model (fig. 39) which has been developed in the year under review. In appearance the new model closely follows the general lines of the 8-inch fan; die-castings are again used for the pedestal and motor housing. A robust yet compact oscillating mechanism is contained within the motor body and there are no exposed cranks or levers ; a patent slipping clutch is also incorporated to safeguard the mechanism and the motor in the event of the arc of osciallation being obstructed. This device is also a feature of the design when the new model is used as a bracket fan. It is particularly convenient, since any 90° arc of oscillation can readily be selected out of the total sweep of 180° available. It is only necessary to " focus " the air stream by turning the motor body, when the oscillation will automatically continue round the selected point.

The fan employs a totally enclosed shaded pole induction motor, fitted with oil retaining bronze bearings. The fan end-bearing, which is self aligning, is in contact with an oil-saturated felt washer providing reserve lubrication, while the opposite bearing obtains additional lubricant from the grease packed gear box.

The absence of a guard, made unnecessary because of the use of rubber blades, creates the impression that the fan is less than 10 ins. in diameter ; on the other hand the performance is surprisingly high for a fan of this sweep. The air displacement is 900 cu. ft. a minute with a peak velocity of 770 ft. a minute ; the current consumption is 30 watts. The fan is finished in silver grey with black blades, and controlled by an " on "/" off " push button switch mounted in the base. It is hoped that production will start in the late spring or early summer.

EMERGENCY UNIT.

The Fan and Small Motor Department is also responsible for selenium rectifiers and has introduced a portable automatic emergency lighting unit incorporating a 6 volt battery, trickle charger and powerful floodlight. The unit can be installed anywhere where life or property would be in danger as the result of a sudden and unexpected failure of the A.C. lighting supply, to which it is normally connected ; immediately the supply is interrupted the floodlight is automatically switched on. The resumption of the supply switches off the

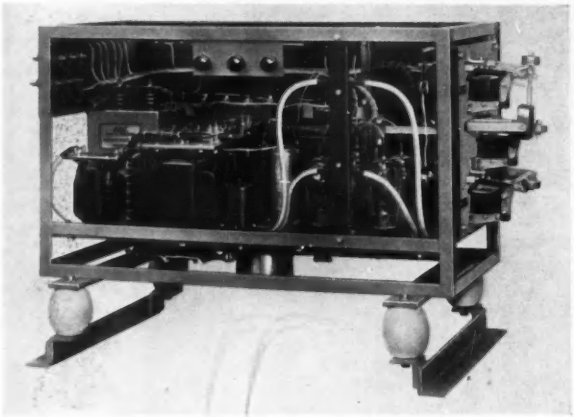

Fig. 40.—Electronic arc suppression unit.

floodlight and reconnects the trickle charger.

The whole unit is contained in a metal case with carrying handle, measuring 18 ins. by 13 ins. by 6 ins., with a 6 in. diameter floodlight mounted on a bracket on the top. A 2-pin socket outlet is also provided to enable two lights to be used if required.

A.C. Motors.

Three frame sizes have also been added to the range of totally enclosed, fan-cooled A.C. motors which now include machines of outputs of 1, 2 and 3 h.p. at 2,850 r.p.m. and 1,440 r.p.m.; 1 and 2 h.p. at 960 r.p.m. and 1 h.p. at 700 r.p.m. These additions provide a complete range of motors from 1 h.p. upwards.

ELECTRONICS.

Electronic Control.

An important application in the field of electronic control has been the development and putting into service of high-speed electronic arc suppression units on the grid-controlled mercury arc rectifiers supplied to the Netherlands Railways. There are, in all, sixteen of these arc suppression units incorporating the triple frequency method of tripping patented by the Company (British Patent No. 589161). The arrangement is such that a triple frequency signal derived from the A.C. supply to the rectifier transformer is used to actuate the thyratron type valves, which in turn actuate the arc suppression of the control grids of the rectifiers. The electronic equipment is chassis mounted and can be easily slipped into place or withdrawn for inspection. A typical view of one unit is seen in fig. 40.

As an indication of the wide possibilities of electronic control, mention may be made of a totally different application in connection with the automatic weighing equipment for a conveyor belt system. Fig. 41 shows an example of the type of electronic control gear supplied to Imperial Chemical Industries.

Another application of electronic control is the servo type amplifiers for the cascade exciters used respectively in the control of the flying shear on the continuous hot strip rolling mill, and also on the temper mill, of the Steel Company of Wales. The former amplifier provides the precision control of the flying shear to give the exact length of cut strip; the latter maintains the correct tension in the strip during acceleration and retardation. As the working speed is about 4,500 ft. a minute, extreme accuracy of control is essential; for this reason electronic means are employed.

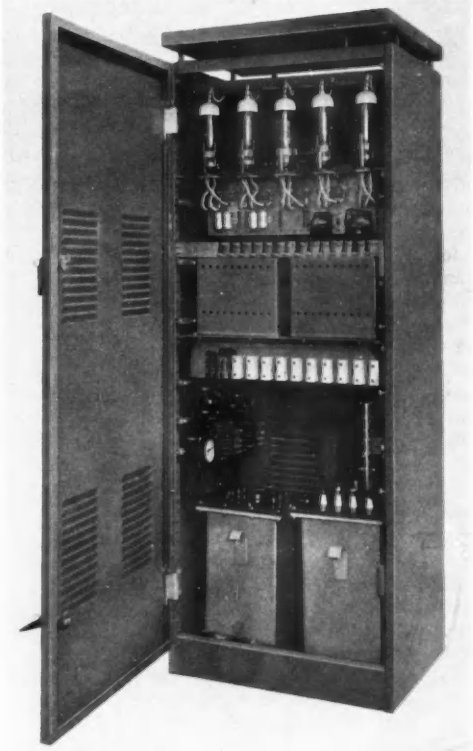

Fig. 41.—Electronic unit for the control of automatic weighing equipment.

A novel and important application of electronics to the textile industry concerns the removal of static electrical charges from threads undergoing certain processes prior to weaving. This is accomplished by an "electric wind" which is a stream of ionised air produced by the corona discharge from sharp points at high potential. In order to remove the risk of shock inherent in equipment of this nature, an electronic high frequency oscillator has been developed to provide the high voltage supply to the discharge combs. By this means the discharge can be rendered perfectly harmless to the touch and yet remain thoroughly effective for removing the static charges.

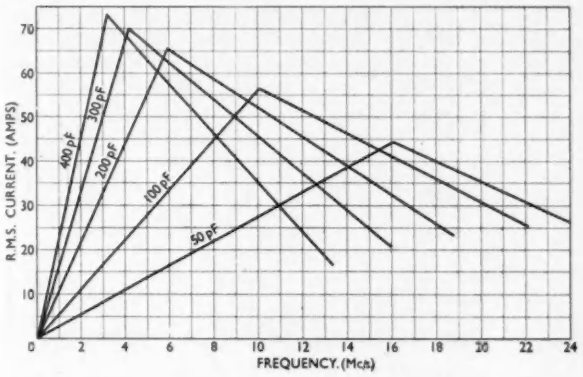

Fig. 42.—Curves of current/frequency rating of vacuum capacitors.

Vacuum Capacitors.

In the article "Electrical Progress and Development" which appeared in this Journal in January, 1951, reference was made to the introduction of the vacuum capacitor. Since that time these capacitors have been produced in a number of standard ranges from 50 to 500 pF, performance curves of which are shown in figs. 42 and 43. These capacitors consist of concentric coaxial copper electrodes sealed into a glass envelope which is subsequently exhausted, thus creating a vacuum dielectric. The electrodes are brought out to fixing lugs mounted on glass/metal seals at each end of the envelope.

The advantages of this type of capacitor in comparison with solid dielectric types are briefly summarised below.

Stable dielectric constant of unity unaffected by changes in humidity or temperature.

Stable breakdown voltage independent of humidity or atmospheric pressure.

Low loss, since there is no solid dielectric to contribute any loss.

A minimum of maintenance is required as dust cannot penetrate to the electrode system; severe external contamination can be tolerated before the breakdown voltage is appreciably lowered and cleaning becomes necessary.

The R.F. current carrying ability of condensers of this type makes them ideal for use in large industrial and transmitting equipments.

The capacitors are compact, mechanically strong and resistant to severe vibration.

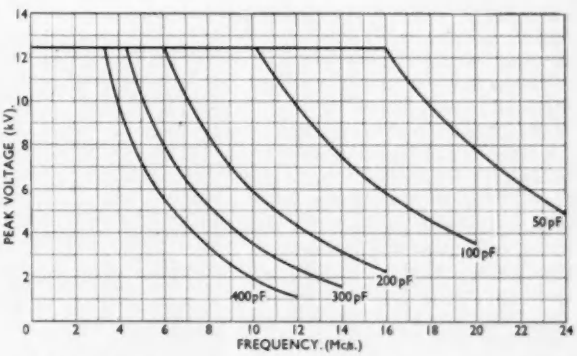

Fig. 43.—Curves of voltage/frequency rating of vacuum capacitors.

Photo-electric Press Guard.

A photo-electric press guard* has been developed in view of the advantages accruing from the use of light rays to safeguard the operator in place of the usual mechanical guard. The equipment consists of two vertical columns at the front of the press, one at each side. One column carries a lamp house, which projects a modulated beam of light across the intervening space on to a mirror on the opposite column. The beam is then reflected back and forth by a series of mirrors so that the whole area between the columns is traversed by the beam, forming a barrage of light rays. The reflection from the last mirror falls on to a photo-electric cell. By

* British Patent Application No. 13862/49.

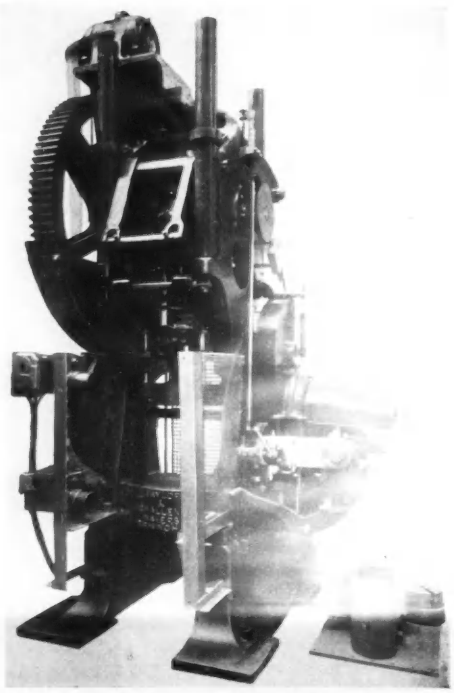

Fig. 44.—Photo-electric guard fitted to a Taylor and Challen power press.

means of valve amplification the impulse operates a relay which locks the press so that it cannot be used while any part of the operator is interrupting the light beam, and is consequently in the danger zone. Thus the press can function only when the beam is unobstructed by the operator or any other object. If the operator places his hand in the danger zone while the tool is descending the press is automatically halted by means of a solenoid which declutches the driving shaft and immediately applies a brake. Interlocked with the press is an automatic checking device which functions at each complete stroke, thus giving an overall check of the electronic equipment so that, in the event of a fault developing in any part of the system, an audible warning is given and the press is stopped. This ensures that the operator shall not continue to work under a false sense of security. It should be noted that the use of a modulated light beam prevents the photo-electric equipment being affected by external lighting conditions. A general view of the photo-electric guard fitted to a Taylor and Challen power press is seen in fig. 44.

PLASTICS.

Recent years have seen a rapid development in the art of the injection moulding of thermoplastic materials. This has been due largely to the introduction and development to large scale manufacture of polystyrene and polythene ; the development of automatic injection moulding presses of continually increasing size has been closely linked with the extremely good moulding properties of these materials.

The Witton Moulded Insulation Works is taking an appropriate part in this development so far as moulding is concerned. The materials have properties that are of particular interest in the manufacture of components for many of the Company's products. Both have outstandingly good electrical properties, good mechanical strength and freedom from odour. Polythene has great flexibility and polystyrene, which in the clear form has optical

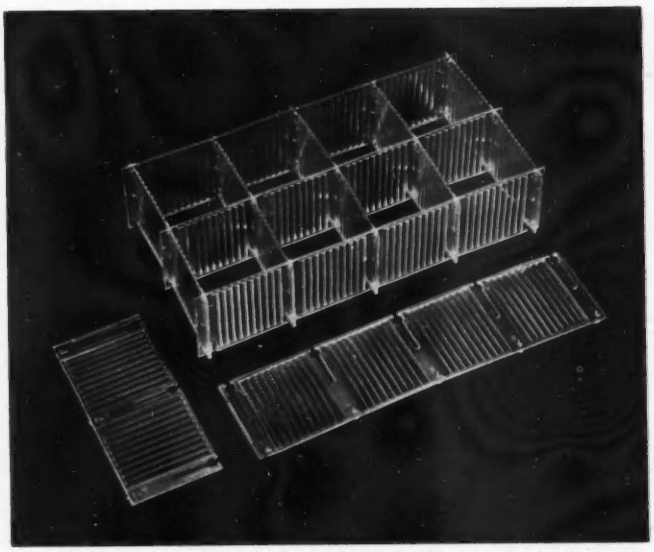

Fig. 45.—Diffuser for a lighting fitting assembled from moulded polystyrene strips.

qualities comparable with glass, is available in an extensive colour range. Consequently, polythene and polystyrene mouldings are of particular interest to those sections of industry concerned with lighting and food preservation.

During the year under review the Works has begun production of a range of mouldings for fluorescent lighting fittings. The individual mouldings, clear or opal, are cemented or riveted together to form a variety of fittings, thereby achieving flexibility of production with the minimum of tooling. A typical example is the diffuser for a lighting fitting, assembled from moulded polystyrene strips, seen in fig. 45. As regards food preservation, refrigerator components such as food containers in polystyrene (fig. 46), latch hole covers and shelf supports in polythene are already in production ; many other applications are in course of development. To meet the increased demand, additional automatic injection plant has been installed which can produce mouldings up to 2 lbs. in weight as compared with the previous maximum of 8 ozs.

Fig. 46.—Polystyrene food container for use in a refrigerator.

WELDING EQUIPMENT.

Safety Electrode Holder.

One of the few disadvantages of transformer type arc welding is the increased risk of shock. Electrode holders, even when fully insulated, do not entirely overcome the trouble since they lose their main safety feature when the electrode is inserted and thus becomes alive. The problem can be solved only by isolating the holder from the supply when not in use, and an insulated holder embodying this feature has now been developed. It comprises a simple switch in the handle whereby the holder and electrode are automatically isolated from the supply immediately the operator releases his grip. It permits continuous welding up to 300 amps. A.C. and takes electrodes up to 4 s.w.g. Isolating contacts in the handle are operated by depressing a lightly loaded spring lever along the body of the holder. The switch will interrupt the highly reactive welding current many hundreds of times without failure.

To prevent the safety feature being deliberately put out of action by tying the operating lever in the " on " position, the design is such that electrodes can be inserted and withdrawn only when the switch is in the safety position.

ILLUMINATION.

Fluorescent Lamps.

Of all the factors influencing the life of the fluorescent lamp the performance of the cathodes is one of the most important, and the continuous improvement in lamp life since this form of light source was introduced in 1939 has been due largely to improvements in methods of retaining the emissive material within the cathode coils. For some considerable time the life performance of lamps under normal conditions of operation has been in excess of the declared figures. Some idea of the extent to which progress in lumen output has been made may be gained by comparing the present average luminous efficiency of 40 to 44 lumens per watt for various lamp ratings over a life of 5,000 hours with the declared average efficiency of 38 to 43 lumens per watt for a life of 3,000 hours. It will be seen, incidentally, that increase in lamp life has been accompanied by improvement in lumen maintenance—an essential point if longer life is to be economically justified.

Work has also continued on the questions of colour and colour-rendering. Although it is interesting to note that recent American trends in fluorescent lamp colours are bringing them closer to established British practice it remains a fact that experience alone can decide the optimum characteristics of white colours for particular applications. Not the least of the difficulties is to cover the range between the " cold" light for colour-matching processes and a " warm " tone for social purposes while avoiding an embarrassing multiplicity of colours, but it is hoped to be able to cater for all important applications without going beyond the five main colours at present in use.

Photo-electric methods are now being applied for the objective measurement and control of fluorescent lamp colour and for investigations into general colour problems. A binocular

viewing technique* has been used for studying the question of the subjective effects† that occur under different conditions of lighting, decoration and vision. These effects make it necessary to provide data to the lighting engineer and the designer of the decorations that will enable them to co-operate to produce a harmonious result, particularly where fluorescent lighting is involved. Conclusions so far reached by the use of this technique indicate that it may prove to be a means of appraising a lighting installation in simple model form under subjective conditions obtained in practice.

The improvement of existing phosphors and the discovery of new ones form an important part of development work on fluorescent lamps, as the longer lives of cathodes can be fully utilised only if phosphors in regular use can be made to yield a higher maintenance of light output. A great deal of interest centres on phosphors that emit efficiently in the red end of the spectrum

Fig. 47.—Underwater floodlight.

and a new class, showing considerable promise in this direction, has been evolved. This development may well be applicable to high-pressure mercury vapour fluorescent lamps, as well as to the more usual low-pressure types, and may lead ultimately to the production of the high-power illuminant of good colour-rendering properties and high luminous efficiency for which the lighting engineer so frequently asks.

The work of Destriau in France on the phenomenon of electroluminescence and its possible application to lighting* has aroused some interest in recent years. Destriau has shown that it is possible to excite certain phosphors to luminesce in an alternating field, and experimental light cells have accordingly been made up in which the phosphor, suspended in a suitable resin, forms the dielectric of a capacitor. One of the plates of the capacitor consists of a transparent conducting film on glass, the other being a metal plate or metallic film in close contact with the phosphor layer. Application of a suitable alternating voltage between the plates causes the luminescent material to glow, but brightnesses so far achieved are not high enough for illuminating engineering purposes. Efforts are being made to improve the light output and efficiency of these "luminous capacitors".

Fig. 48.—Ceiling eyeball spotlight.

Mercury Lamps.

Evidence of growing acceptance of the 1,000 watt mercury lamp as a means of high bay lighting is provided by the knowledge that considerable numbers are now in use in large works. The average luminous efficiency throughout the life of this lamp has been increased from 45 to 48 lumens per watt.

A 2½ kW A.C. cadmium-mercury compact source lamp has been developed : this is similar in form to the D.C. lamp of equal rating now accepted for use for cinema studio lighting.

High-wattage, high-pressure mercury discharge lamps are well known for their application to photo-printing, and the Osram 400 watt and 1 kW lamps of this type are now established for certain aspects of this work. There is increasing interest in the possibilities of using low-

* "Colour and Lighting" (Part 2), by G. T. Winch and Brenda M. Young, *G.E.C. Jour.*, Vol. XVIII, No. 2, p. 88, April, 1951.

† "Colour and Lighting," by G. T. Winch, *G.E.C. Jour.*, Vol. XVI, No. 4, p. 197, October, 1949.

* *Phil. Mag.*, Vol. 38, p. 700 (1947).

pressure fluorescent lamps for similar work, and experiments suggest that a lamp with the spectral emission characteristics of the existing blue fluorescent lamp would be satisfactory.

In two previous Progress Articles reference was made to the development of special mercury isotope discharge lamps for laboratory use : a few lamps have now been made with a filling of the krypton isotope 84, which was prepared for the purpose in the University Institute for Theoretical Physics in Copenhagen. This isotope, like the mercury 198, yields a nearly ideal monochromatic radiation, and the use of one or other of them is being seriously considered in connection with the establishment of an international standard of length in terms of a wavelength of light. Two types of krypton isotope lamps have been made, one fitted with thermionically emissive electrodes, the other electrodeless and operated in a water jacket.

Fig. 49.—Industrial type reflector for 1 kW high-pressure mercury lamp.

The few lamps at present available are being studied and compared with mercury 198 sources at the National Physical Laboratory, Teddington, preparatory to a forthcoming General Conference on Weights and Measures.

Tungsten Filament Lamps.

As a result of the increasing popularity of silica-coated lamps, due to their diffusing property and small light absorption, the range of " Silverlight " lamps has been extended to ratings up to 200 watts. Photographic enlarger lamps are now supplied with the internal silica coating, in order to overcome any tendency towards a granular effect in the enlargement traceable to the light source. They are the same size as the ordinary 60 watt lamp, but have a special 150 watt filament which, operating at a higher colour temperature, considerably reduces exposure times.

A range of lamps with natural colour glass bulbs having transmission properties that make them suitable for use as " Safelights " in photographic darkrooms will be available shortly. Development is continuing on blue-coated Photoflash bulbs for use in outdoor colour photography ; these would supply local lighting where necessary to counteract deep shadows frequently encountered in brightly sunlit scenes.

New types of aircraft landing and aerodrome runway lamps have been produced, as well as new 2½ kW and 4½ kW types for marine lighthouses. The 4½ kW lamp has a cylindrical filament structure designed to give a uniform beam in all directions.

Glass Manufacture.

The Osram-G.E.C. Glass Works now has at its Lemington factory a plant developed by the Research Laboratories for the manufacture of special tank blocks. This will produce better refractory materials for the furnaces, a matter of considerable importance, since highest quality glass bulbs and tubing are vital to successful lamp manufacture. The blocks, also developed in the Laboratories, are fired at a very high temperature and are far more resistant to the attack of molten glass than other commercially available refractories of a similar type.

The successful development of external enamelling of lamp bulbs has been applied to the production of a range of red, blue, green, yellow, orange and white bulbs, while internal enamelling of machine-drawn tubing has also been developed and will shortly go into production. An automatic cutting and glazing machine is now used in fluorescent tubing production to give an accurately controlled length to the lamp maker.

New Lighting Equipment.

New lamps and new lighting applications give rise to constant demands for fresh forms of lighting equipment. One example is a novel underwater floodlight (fig. 47) designed initially for use at the Festival of Britain. It employs the " diving bell " principle and, since the water inside the unit is kept down to a safe level by the pressure of the air locked inside the cover, no watertight joint is required between the

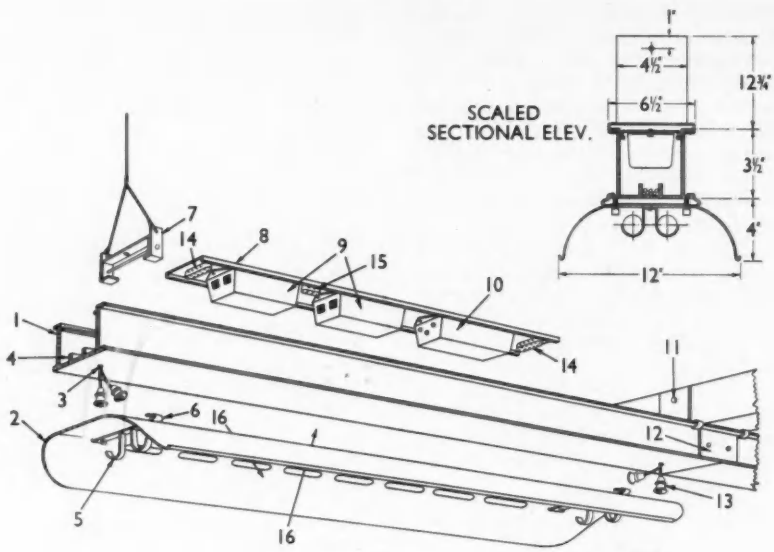

Fig. 50.—Continuous trunking system.

1. Extruded aluminium trunking.
2. Sheet steel reflector.
3. Hole for lampholder leads drilled on site.
4. Wiring runs.
5. Lamp support.
6. Reflector supporting strap (slides on to trunking.)
7. Suspension bracket (wire or rod suspension).
8. Control gear tray.
9. Combined choke and instant start units.
10. Capacitor.
11. Fishplate for attaching trunking to beams.
12. Fishplate for joining lengths of trunking.
13. B.C. lampholders (Home Office shielded pattern).
14. Four-way terminal blocks.
15. Two-way terminal block.
16. Slots for upward illumination.

glazed cylindrical cover and the base incorporating the lampholder. Fig. 48 shows another new unit, intended for sunk mounting in the ceilings of shop windows or other display spaces where emphasis or high lighting is required. Designed for use with the 150 watt mirror spot lamp, it is in the form of a swivelling " eyeball " with concentric ring louvres to limit the spill of light outside the beam.

A new industrial reflector (fig. 49), produced for the 1 kW high-pressure mercury lamp, embodies a spun aluminium main reflector with an anodised inner surface and a dual-purpose slotted canopy. This canopy permits a cooling through-draught of air and minimises the deposition of dirt on the reflecting and lamp surfaces. Light distribution is concentrated downwards so as to avoid the excessive wastage of light on walls which is otherwise likely to occur owing to the considerable mounting heights usual with such large light sources.

In many industrial installations of fluorescent lighting, the fittings are mounted close together in long lines, and to meet these requirements in a simplified form the continuous trunking system shown in fig. 50 has now been devised. The trunking is made from extruded aluminium and is sufficiently large to contain lamp auxiliary gear, supply wiring and cables for other purposes such as power, signals, and the like. In present circumstances a similar design in steel has had to be adopted. Reflectors may be attached independently to the underside of the trunking to conform to any lighting plan, while suspension of the trunking itself can be arranged at points to suit the roof structure.

For more decorative purposes cellular louvres are gaining in popularity, especially when used with fluorescent lamps. Metal louvres of this type are heavy and must be fabricated at the fittings works, but an alternative design in polystyrene, in flat unit form, enables the individual elements to be supplied in a solid pack. The units are assembled on site into square or oblong elements, which lock together by means

Fig. 51.—The Church of St. Peter Mancroft, Norwich, lit by concealed fluorescent lamps.

of keyed slots moulded into them. An attractive appearance is given to the completed louvres by the prismatic form pressed into the units during manufacture.

Calls continue for special operating circuits. For example, it is well known that fluorescent lamps become difficult to start at temperatures of the order of −15 degs. C., which are common in cold storage buildings, and even lower temperatures are experienced in certain street-lighting applications. For such conditions new circuits have been devised which permit satisfactory operation of two 2 ft. 20 or 40 watt lamps in series, or single 4 ft. or 5 ft. lamps. Adequate light output at these low temperatures is ensured by the use of completely enclosed fittings. The circuit, described in the last Progress Article, for operating 2 ft. lamps at 850 cycles for the London Transport Executive has been extended to 5 ft. lamps. A circuit that prevents, under conditions of lamp failure, any excessive rectified component of operating current has made possible the use of 5 ft. 80 watt instant start lamps with capacitive control. For hospitals and other places where emergency lighting from accumulators must be available, circuits have been developed for the operation of fluorescent lamps from normal A.C. supply or D.C. emergency supply at will.

Fig. 52.—East Ham Town Hall illuminated by fluorescent lamps in decorative pendants.

Control Gear.

(*a*) *Welding Jig:* A jig has been designed to clamp, set and weld the 40 watt brick choke used with fluorescent lamps. The choke is clamped by a cam and set by tightening on a screwed rod. The electrodes being vertical and lying along each side of the choke, both sides are welded simultaneously, and a relay cuts off the welding current when the electrode burns beyond the top of the

Fig. 53.—Fluorescent lighting in the Main Banking Hall of the Midland Bank, Poultry, London.

choke and the arc voltage increases. The jig is mounted on a turntable with a semi-circular shield, enclosing all live parts, round the back.

(*b*) *Thermal Conductivity in Chokes:* Another development is an apparatus for measuring the thermal conductivity of high melting point bitumens used in brick chokes. It comprises a water jacket and a central tube containing the sample, the tube being removable for filling and emptying. The heating element consists of a copper tube through which a heavy current is passed. The voltage drop on the tube is measured and, as the watts input and the temperature of the water jacket are known, the power conducted as heat through the specimen may be ascertained in watts/cm./deg. C.

(*c*) *Tandem Transetter:* A tandem transetter has been designed and built in the Development Laboratory of the Witton Engineering Works, for setting and checking the secondary voltage of tandem transformers providing the high-voltage supply for cold cathode fluorescent tubes. An 8 in., 0-5 milliammeter records the difference between the secondary current of the transformer being set and that of a standard, when feeding a given resistive load. A simple, manually operated lever system adjusts the iron circuit of the transformer until the difference current is zero. Short circuit performance is checked on the same meter by a press button. Features of the equipment include complete protection of the operator from high voltages and protection of the meter against high difference currents which may be produced by possible

Fig. 54. — Cold cathode lighting in the "Empress of Scotland"

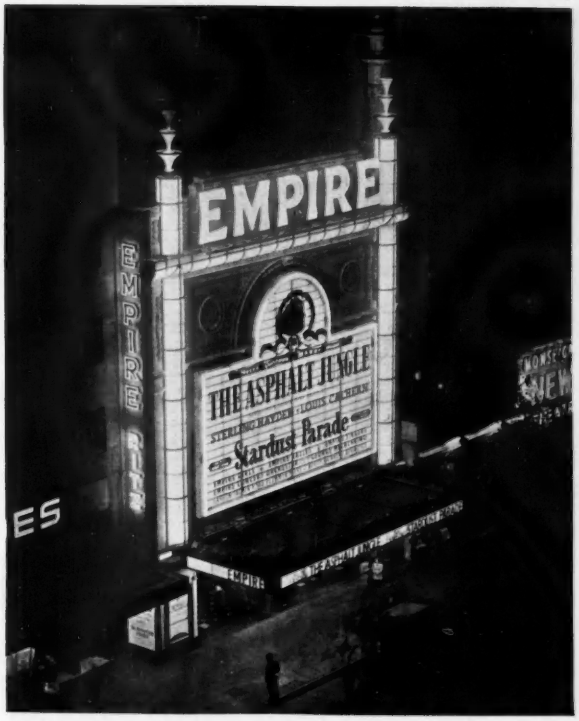

Fig. 55.—Display lighting at the Empire Theatre, Leicester Square.

open circuits in the product. It is to be noted that the equipment easily handles all transformers of this type produced at the factory.

Lighting Installations.

Two memorable schemes carried out lately, those in the new Chamber of the House of Commons and in the Royal Festival Hall, have been described in recent issues of this Journal.

Among other installations completed during the past year are those at St. Peter Mancroft Church, Norwich (fig. 51), which has been re-lighted very successfully by means of concealed fluorescent lamps ; East Ham Town Hall (fig. 52) where fluorescent lamps have been housed in large decorative pendants, and the main banking hall of the Midland Bank Head Office (fig. 53), where circular pendants have been redesigned to accommodate cold cathode tubes. A notable example of ship lighting is to be seen on the liner "Empress of Scotland" (fig. 54), where cold cathode lamps are extensively used.

Interest in the possibilities of dimmer-controlled fluorescent lamps has been stimulated by the successful dimming installations in the House of Commons and the Royal Festival Hall, and transductors giving a dimming ratio of 500 to 1 have been designed. One of the first commercial installations of this lighting has been completed in the auditorium of the South Western Electricity Board's demonstration theatre at Bristol Electricity Service Centre.

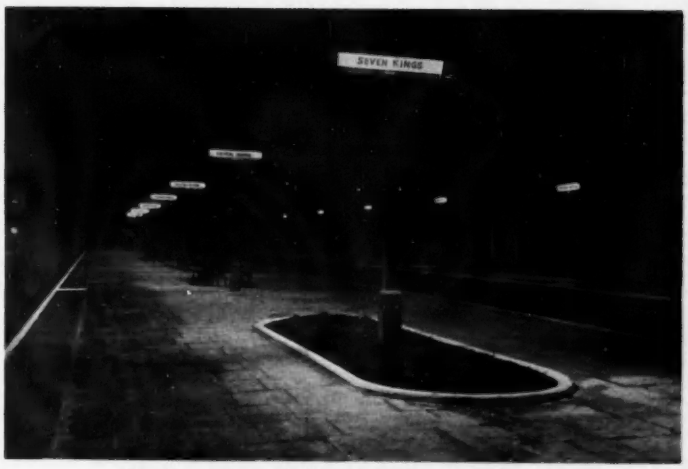

Fig. 56.—Railway platform lit by fluorescent lamps.

Fig. 57(a).—Single "Difractor" lantern: vertical lamp.

Fig. 57. — Distribution of luminance from various lanterns at a height of 25 ft., from 200 ft., asphalt surface. Values are in ft. lamberts. The grid shows angles in azimuth and elevation from lantern, corresponding to polar distribution network.

Transductors control 5 ft. lamps housed in indirect beam features.

EXTERIOR LIGHTING.

The new installation at the Empire Theatre, Leicester Square (fig. 55), for which Claude-General Neon Lights, Ltd. has been responsible, is an example of the elaborate methods often used for display and advertising purposes. Each of the two 50 ft. high semi-circular columns of fluted glass contains fifteen high-tension discharge tubes coloured blue, green and red, and a horizontal section is equipped similarly. The world "Empire" also contains the three colours. Independent operation of the columns permits a continuous colour change with a very wide range of combinations. Programme lettering appears in silhouette against a background of opal glass, behind which is white high-tension tubing. The lighting under the canopy of this theatre is also by means of cold cathode tubing of which, it is interesting to note, there is almost exactly a mile in the complete installation.

More utilitarian is the railway station platform lighting seen in fig. 56. This installation employs fluorescent lamp units specially designed for use on the Liverpool Street to Shenfield section of British Railways (Eastern Region). The lantern houses two 5 ft. 80 watt lamps, and when mounted at a height of 12 ft. 6 ins. at a spacing of 40 ft. about one lumen per square foot is given over the platform area. The unit has been designed to resist the effects of weather and dirt in the atmosphere.

Fig. 57(b).—Single "Dioptrion" lantern: horizontal lamp.

Fig. 57(c).—Single " Blown cut-off " lantern: horizontal lamp.

During the past year the relative merits of horizontal and vertical mounting of high-pressure mercury vapour lamps in street lighting lanterns were studied. There is a general preference for horizontal lamps, used in lanterns such as the " Dioptrion," since they permit more accurate control of the light in vertical planes and produce a wide distribution particularly suitable for lighting winding roads. Nevertheless the use of the vertical lamp has numerous practical advantages : it is simpler and cheaper and produces a light distribution which, affording greater flexibility in siting, is well suited to many situations.

Some users, however, insist that the horizontal lamp produces a wider patch of bright light on the road surface than the vertical source, a particular advantage on wide thoroughfares. An experiment with the object of establishing the facts was carried out in Bromley Road, Catford, with the permission and co-operation of the Borough Engineer, Mr. J. Carr, and of Mr. T. W. E. Pring, of the London Electricity Board and his staff. Three single lanterns were set up and carefully photometered in the Laboratory and were then erected and aligned with special sights on the same column in turn. The illumination of the roadway and the brightness of the surface as seen from a distance of 200 ft. were studied for each lantern on the same night by several methods, including photographic photometry, every precaution being taken to ensure that the observations were made under identical conditions.

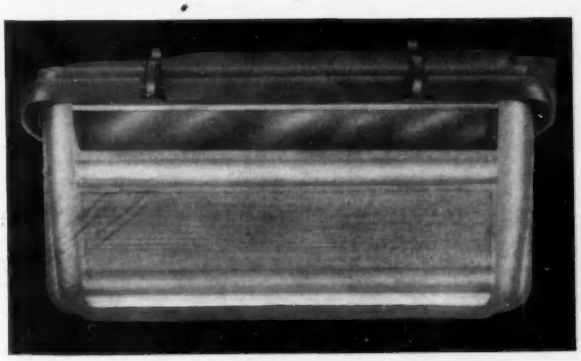

Fig. 58.—" Two-forty " fluorescent lantern.

The three lanterns were (*i*) 400 watt " Difractor " (vertical lamp); (*ii*) 400 watt " Dioptrion " (horizontal); and (*iii*) 400 watt " Blown cut-off " (horizontal lamp). The results as determined by photographic photometry (which checked well with those of other methods) are demonstrated in figs. 57(a), 57(b) and 57(c).

It will be seen that the bright areas from the first two lanterns are almost exactly the same. The only differences attributable to the lamp position are in an insignificant corner close to the head of the " T ", notwith-

standing the considerable difference in the width of the light distribution peaks. The importance of light distribution on vertical planes is, however, shown by the result for the cut-off lantern, where the characteristic patch without a " tail " necessitates closer spacing of the lanterns.

Fig. 59.—Post-top mounting lantern.

This experiment, confirming conclusions reached in theory, indicates that, in appropriate streets and with properly designed lanterns, either vertical or horizontal lamps will give good results ; the bright patch is no wider using horizontal lamps in lanterns of normal size. Even in the case of large lanterns using fluorescent lamps horizontally there is little significant advantage in the width of the bright patch except when the road is wet or very highly polished.

The usefulness of such investigations will be apparent in the design of new lanterns. The main emphasis during the past year has been on the application of fluorescent and sodium lamps, both growing in popularity. A range of lanterns housing respectively two, three and four 80 watt fluorescent lamps is now available, the lamps in each case being enclosed by a V-sectioned bowl of " Perspex " acrylic sheet having " Perspex " refractor plates cemented to the insides. The prisms are completely enclosed, thus leaving both the inner and outer surfaces of the bowl smooth and easy to clean. By the use of plastics and aluminium alloys, lanterns of this type may be made light and strong despite their necessarily large size.

Similar constructional principles are followed in the case of the lantern shown in fig. 58, which is designed to accommodate two 2 ft. 20 or 40 watt fluorescent lamps. A special feature of this unit is that the lampholders are mounted directly on to the inner surface of the bowl to ensure positive location of the lamps relative to the refractor plates. The gear to operate the lamps is housed within the lantern body on a hinged tray, the underside of which forms an over-reflector.

A lantern designed for side-street lighting by means of either a 45 or 60 watt " Osram " sodium lamp again has a die-cast light alloy body with " Perspex " refractor plates cemented directly on to a " Perspex " bowl. It is intended for mounting at a height of 13 to 15 ft., with a spacing of 100 to 120 ft. between columns. This lantern is also available in a form which enables lamp auxiliary gear to be housed in an enlarged canopy, a convenient and economical arrangement where it is desired to make use of existing columns which may have no accommodation for auxiliary gear.

A simple yet extremely effective lantern for sodium lamps, intended particularly for main roads where only the cheapest equipment can be afforded, has a body consisting of two iron end-castings held rigidly by tie rods. It has a galvanised and stove enamelled top, and an optical system of curved silvered glass mirrors.

Among other new side-street lanterns is one with a cast iron body of simple construction and clean lines, with a dome refractor optical system for tungsten filament lamps of 60 to 200 watt ratings or mercury lamps of 80 to 125 watts, while

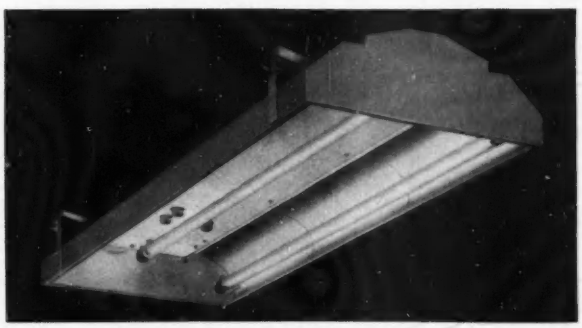

Fig. 60.—" Three-eighty " cut-off lantern.

for the same range of lamps a lantern designed with particular regard to attractive appearance is illustrated at fig. 59. This type is for mounting on a post top and is especially suitable for promenades, public gardens and similar areas. The light is controlled by a dome refractor, sur-

Fig. 61.—Two-beam aerodrome runway light.

rounded by a truncated cone of fluted " Perspex," and the cone base is completed with diffusing " Perspex " to afford some light at the foot of the pole.

Also in decorative style is a vertical lantern housing 40 watt tubular fluorescent lamps in an opal " Perspex " cylindrical body enclosed at top and bottom by opal dishes of the same material.

Fig. 60 shows a cut-off lantern designed to solve the special problems that arise in lighting tree-lined roads, particularly those of great width often found abroad. This lantern accommodates three 5 ft. 80 watt fluorescent lamps, the light being controlled by reflectors. Rope grips are fitted to facilitate suspension from twin span wires and the control gear may be housed inside the lantern, or elsewhere if it is desired to reduce the weight on the span wires. On most roads not wider than 80 ft. the lanterns should be mounted in a straight row down the centre at a height of 25 to 30 ft. A double row is desirable on wider thoroughfares.

Airport Lighting.

The design of airport lighting equipment which is required to give aid to pilots is of paramount importance. A new elevated two-beam runway light, which will be used on the Jan Smuts Airport at Johannesburg, is shown at fig. 61. This incorporates two main beam lamps up to 100 watts rating each, and can give intensities of more than 100,000 candelas with considerably greater beam divergence than is usual in flush-mounted units. The light illustrated in fig. 62 employs an optical system much the same as the standard G.E.C. ZA 202 flush taxi light but is designed for use in places where flush mounting may be unsuitable because of snow or sand.

Both the lights illustrated have the transformer box combined with the light to form a single unit intended for mounting off the edge of the paved track. Each unit is structurally designed so as to break off at the joint between the lid of the transformer box and the base of the stem (in which there is an electrical disconnecting device) in the event of its being accidentally struck. The transformer box has a double

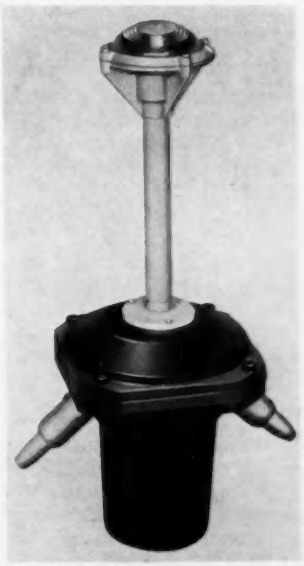

Fig. 62.—Elevated low intensity runway light.

lid so as to remain watertight even when the top of the light is damaged.

Fig. 63 shows a searchlight for illuminating damaged aircraft or other obstructions on runways or taxiways. It is intended for roof mounting and manual operation by means of a central column passing through the roof. A 20 in. parabolic reflector is used, with 900 watt

Fig. 63.—Aerodrome searchlight.

to 2 kW lamps according to the size of the airport and likely conditions of visibility.

Fig. 64 illustrates the new ZA 503 airport location beacon which has been designed to comply with the specification of the International Civil Aviation Organisation. It employs a 2¼ kW lamp set at the common focus of four 20 in. diameter prismatic lenses and incorporates a lamp changing device which is automatically operated on failure of the lamp in service. The ZA 752 double obstruction light has been redesigned and the new unit is shown in fig. 65.

Film Studio Lighting Equipment.

Novel demands are often made by the motion picture industry. For example, in one film being made by Twentieth Century-Fox at Denham a small brightly burning object was required to represent material "activated" by atomic disintegration. A grossly overrun mercury discharge lamp, specially made for the purpose, finally solved this problem. Another demand was for a lightning discharge, while on a further occasion there was a request for a lamp that might have been made in 1784 by a person with knowledge of modern engineering techniques, but using only materials available in that year.

As regards normal studio equipment, the past year has seen the introduction of a new spotlight as an extension to the range for use with 2½ kW compact source mercury discharge lamps. This new spotlight (fig. 66) has a 14 in. diameter prismatic lens giving high efficiency and beam intensity.

Industrial and Process Heating Equipment.

A notable achievement in the field of process heating has been the development of a new type of continuous decarburising furnace having vertical heating and cooling chambers and a horizontal decarburising chamber. Very high processing speeds can be obtained with this type of furnace, which makes minimum demands on floor space. A recent installation, developed for the continuous decarburisation of silicon steel strip, comprises a furnace rated at 620

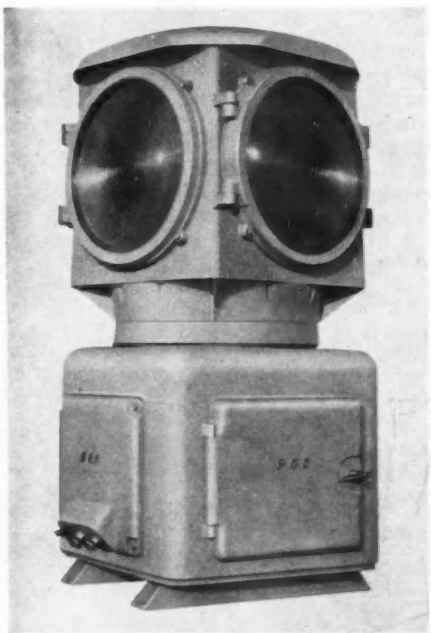

Fig. 64.—The new airport location beacon.

kW, with a maximum operating temperature of 950 degs. C., which will process the strip at rates approaching one ton an hour. The strip is heated as it passes through the vertical chamber, is then held at temperature in the horizontal decarburising chamber and is finally cooled in a water jacketed tower. Photo-electric cell equipment is incorporated to control the catenary dip of the strip. The complete installation is surrounded by a steel platform.

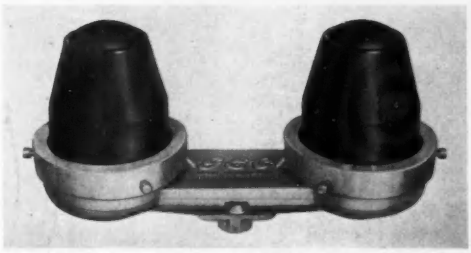

Fig. 65.—New design of double obstruction light.

Another novel type of continuous furnace, the first of its kind to be built in this country, is being supplied to a leading firm of car manufacturers in Paris for the carbo-nitriding of engine gear box parts. This is a pusher type furnace in which the gears are suspended in jigs from a cradle and traversed through the furnace by a hydraulic pusher. It has been designed to process 45 charges per hour, each weighing (with jig) 13·2 lbs. Yet another type of continuous furnace, shown in the outline drawing (fig. 67), is also specially designed for the carbo-nitriding process; in this case the charge is carried on trays.

A large installation of six vertical cylindrical bell type furnaces has been made for annealing silicon steel strip in coils. Each furnace has a maximum rating of 360 kW and is capable of taking a 20-ton charge. The complete installation has eighteen furnace bases and hoods and will process some 700 tons of strip a week. Fig. 68 shows a new roller hearth furnace 120 feet in length and complete with atmosphere plant and auxiliary drive which has been installed for the bright normalising of steel strip in lengths. It has a nominal output of 10 cwts. an hour.

Reference was made in last year's Progress article to the use of infra-red heating to accelerate the drying of wood finishes; this technique has now been applied to a variety of articles including furniture, radio cabinets and the veneered panels used for the interior decoration of ships and trains. For the last named application, infra-red heating is an essential part of the finishing process. In an installation at Saro Laminated Wood Products, Ltd. (fig. 69), the panels, after they have been sprayed with a synthetic resin material, are placed on a woven wire belt conveyor which carries them beneath an 18 ft. long lamp plant; after 5-7 minutes stoving a durable, fire-resistant, plastic coating is produced. Panels up to 5 ft. wide can be handled.

A similar plant has been installed at the Coventry Works of Jaguar Cars, Ltd., for force-drying the cellulose-based finish applied to the interior woodwork of the cars including the walnut veneered instrument panel. The finish would take some twelve hours to dry in air, but with infra-red heating the drying is complete in nine minutes, and the resultant finish has been found not to blister in tropical climates. Although the infra-red heating unit through which the parts are conveyed is only 12 feet long, its capacity is some 10,000 pieces in a forty-hour week, which are sufficient to make 300 complete sets of car woodwork.

An edge gluing machine (fig. 70) has been added to the range of self-contained equipment designed for specific applications of high frequency heating. This machine, the first of its kind to be produced in this country, has been developed jointly with Fielding & Platt, Ltd.,

Fig. 66.—14 in. studio spotlight for 2½ kW mercury lamp.

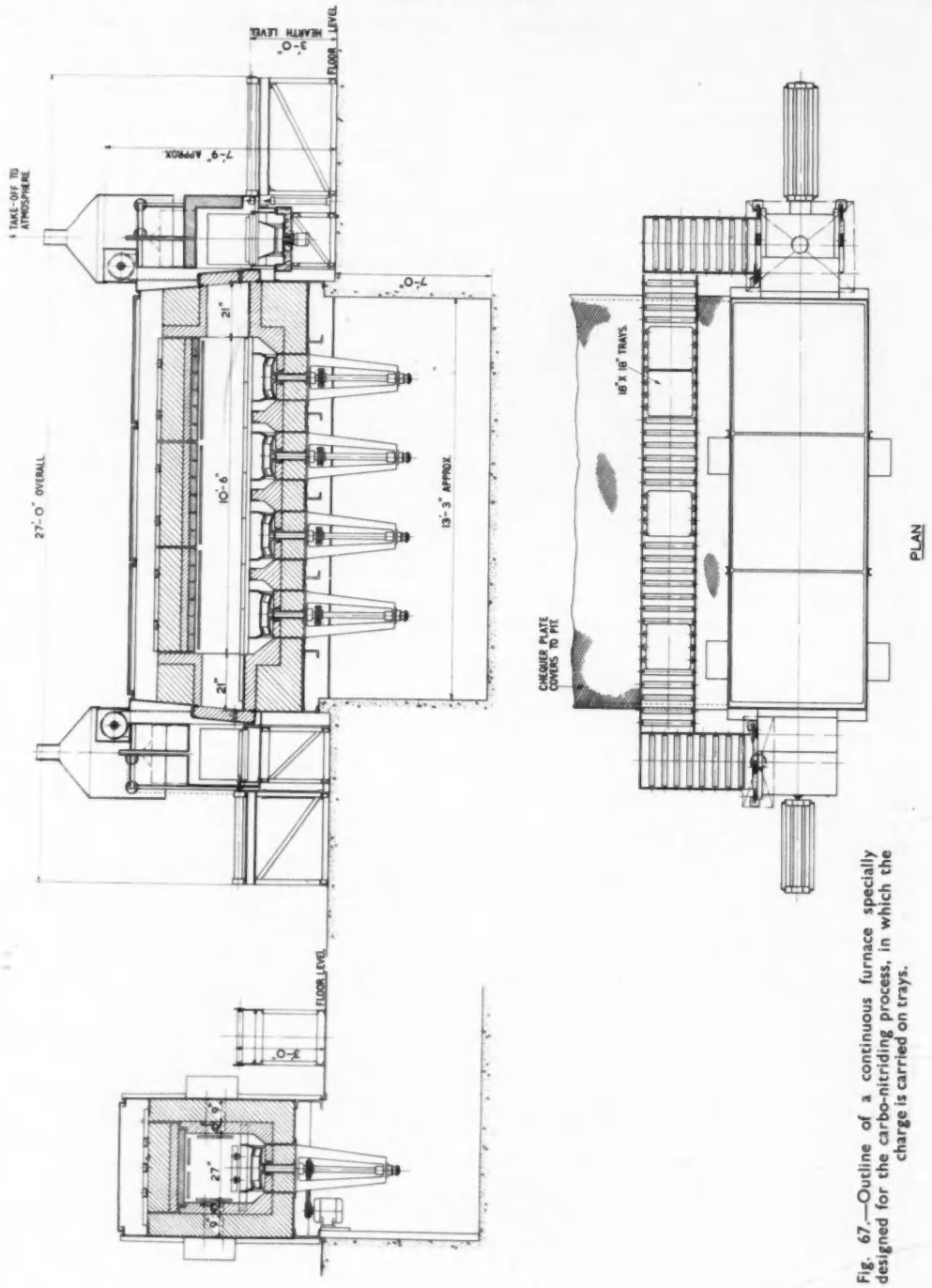

Fig. 67.—Outline of a continuous furnace specially designed for the carbo-nitriding process, in which the charge is carried on trays.

Fig. 68.—Roller hearth furnace installation for the bright normalising of steel strip. The associated atmosphere plant is seen in the background.

the press manufacturers, and is a fully automatic plant for mass-producing block-board or panels by the edge gluing of strips of wood (which may themselves be "waste") of any convenient widths. The plant comprises a 5 kW H.F. dielectric heater, a press and feed table, and a small glue spreading machine. Its operation is extremely simple. The strips of wood are fed through rollers, where the surfaces to be joined are coated with a synthetic resin glue, after which they are assembled on the feed table. A single press-button control then initiates the series of automatic operations required to produce the finished glued board, which includes the application of top and side pressure followed by high-frequency heating. The machine has been designed for the production of boards from 36 ins. to 80 ins. long, up to 40 ins. wide, and $\frac{5}{8}$ in. to 2 ins. thick. A production rate of 12 an hour is obtained for boards 80 ins. long, 40 ins. wide, 1 in. thick; or 40 ins. long, 40 ins. wide, 2 ins. thick, made up in each case of strips 2 ins. wide.

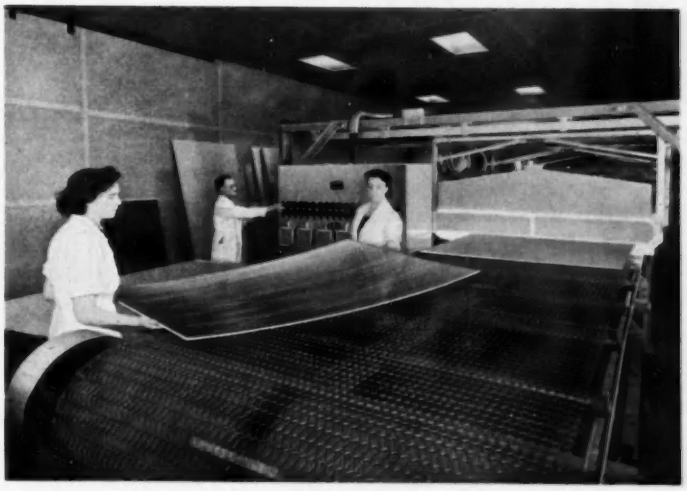

Fig. 69.—Infra-red lamp plant for drying wood finishes. A veneered panel, of the type used for the interior decoration of railway carriages, is being removed after the stoving of its synthetic resin finish.

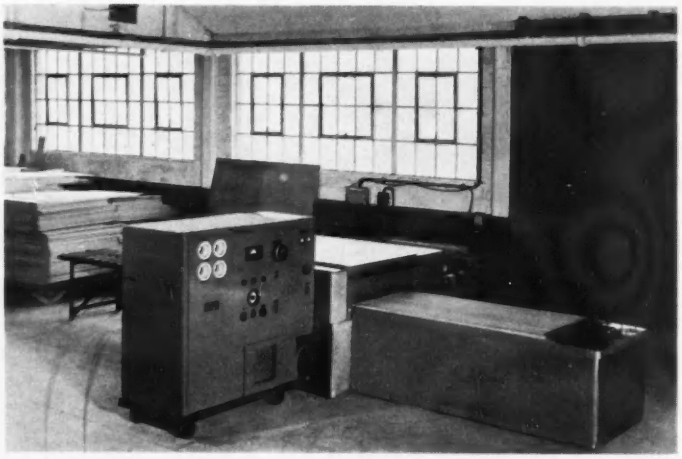

Fig. 70.—High-frequency edge gluing machine for the production of block-board or panels from wood strips.

AGRICULTURAL, MARINE AND DOMESTIC HEATING EQUIPMENT.

The introduction last year of the heat storage block type of dairy sterilising equipment, described in the previous Progress Article, has been followed by the addition of a larger unit of the same kind, which provides steam and hot water simultaneously. This equipment is designed to sterilise up to a 6-unit recorder-releaser milking plant and provide steam to an unlagged sterilising chest of 27 cu. ft. volume and to a stool for churns. The water heater, which has a capacity of 50 gallons, provides sufficient hot water for cleaning the milking machine, including both detergent washing and hot rinsing, and for other necessary washing-up. The electrical loading of the water heater is 2 or 3 kW, and that of the storage block 2 kW. A directly heated steam raiser not making use of the storage principle would require a loading of 20 kW to give the same service.

Two types of drying unit for grain crops, using duct-air heaters and Aerofoil or propeller fans, have been introduced. In one type (figs. 71 and 72) the grain is treated in ventilated bins which provide an economical method of storage under controlled conditions, and in the other (fig. 73) the grain is dried in sacks on a platform. The farmer who has only a small acreage of grain will find the second unit an effective installation obtainable at comparatively low cost.

A combined soil steriliser and greenhouse heater has been produced to meet the requirements of the amateur gardener. The unit (fig. 74) has a capacity of 1 bushel, which amounts to approximately 1 cwt. of soil, and its electrical loading is $1\frac{1}{2}$ kW.

Fig. 71.—Part of ventilated bin installation with an ultimate capacity of 350 tons.

In addition to providing a convenient means of sterilising small quantities of soil for potting and propagating, the equipment will also warm a small greenhouse, a fact which greatly extends its usefulness as it would normally be used as a soil steriliser for only a short period during each season. If it is desired to increase the humidity in the greenhouse the cover of the unit may be turned over and filled with water.

There is a definite trend towards the use of three-phase, 440 volt A.C. generating equipment in place of 110 volt or 220 volt D.C. systems for the provision of electrical services in ships. A complete range of A.C. galley equipment is now available, as mentioned earlier in the section dealing with marine electrical equipment.

The British Standards Institution has for some time been studying methods of improving the safety of both gas and electric fires. A British Standard specifying the safety requirements for electric fires has now been published and its recommendations have been incorporated in a series of new guards designed for the complete range of fires manufactured by the Company. These guards are so constructed that even highly inflammable clothing may be in contact with them for as long as ten seconds without risk of becoming ignited. While this degree of protection is suitable for average conditions in the home, the British Standard emphasises the need for additional precautions for the protection of young children and aged persons. A new nursery fire, shown in fig. 75, has been introduced to meet this need. It gives adequate protection against contact with the elements, has a wide base to provide stability, and may, as a further safeguard, be screwed to the floor. The elements, of 2 kW rating, are housed in a wide angle reflector which disperses heat over an angle of 120° in the horizontal plane.

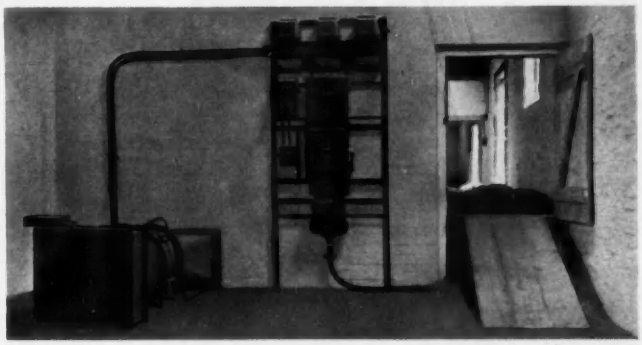

Fig. 73.—Aerofoil fan and duct air heater for platform type of grain dryer.

A high temperature space heating panel has been developed for use in rooms and offices. It consists of a sheathed wire element cast into an aluminium panel with the electrical connections taken to the rear, and is designed for mounting on the wall or suspending from overhead. The surface temperature is approximately 450 degs. F.

Fig. 72.—Aerofoil dual duty fan and duct air heater for drying grain in ventilated bins.

An automatic toaster (fig. 76) has recently been added to the range of domestic appliances. Housed in a pressed-steel, chromium-plated case mounted on a black moulded plastic base, it has a pleasing, smooth-lined finish. The base is raised on four rubber feet to prevent over-heating of the surface on which the toaster stands. The appliance can be carried by two heat-insulating black plastic handles, one at each end. One of the handles is attached to the actuating arm, which passes through a slot in the casing. Depressing this handle switches on the heating elements and also starts the timing mechanism, which, by turning a small control knob, is preset to give the desired degree of toasting. The toaster takes two pieces of bread and when toasting

Fig. 74.—Combined soil steriliser and greenhouse heater.

is complete the bread is raised automatically and can be easily removed. The hinged base incorporates a crumb-tray for easy cleaning.

MEASURING INSTRUMENTS.

Examples of the new range of 3½ in., 6 in. and 8 in. switchboard instruments, briefly mentioned in this Journal in January 1951, are shown in fig. 77. They are available in various complete ranges of uniform appearance and incorporate several novel developments both in design and construction.

The magnets of the moving coil D.C. instruments are of the powerful anisotropic type, giving improved damping, sensitivity and torque, one of the results of which is the reduction of the temperature error in the millivoltmeters to negligible proportions. The induction wattmeters, of both the single and double element types for use on single and three-phase loads, are also characterised by small temperature error, achieved in this instance by the use of a special material for the eddy current disc. The frequency meter is of the Coleman type using "Mumetal" irons; its improved design and special method of coil adjustment during calibration simplify manufacture. A new system used in the power factor meters ensures a high working

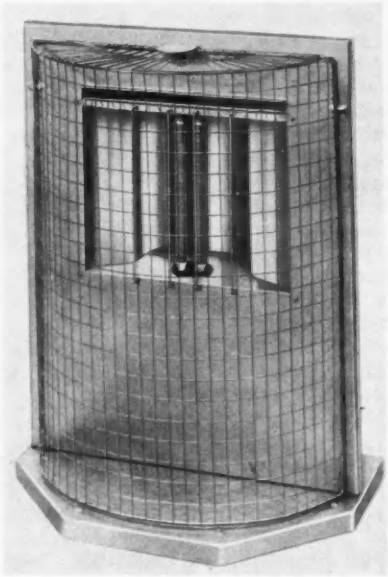

Fig. 75.—New nursery fire with protective guard.

torque at low loads : it consists of an annular core of ferrous material wound with three-phase windings normally connected to current transformers in the three-phase lines. In the rotating field thereby produced are three disc-shaped voltage coils connected to the three phases of the system ; each of these disc coils contains a moving iron core, the three irons being set at 120° to each other on a pivoted shaft, to which the pointer is attached. The shaft takes up a position dependent on the time phases between

Fig. 76.—The new automatic toaster.

the currents and voltages, and the pointer indicates the overall power factor.

The usefulness of measuring instruments, particularly those employed outside a laboratory, is largely determined by their convenience. Ideally, the required information should be given directly by the instrument but if this is not possible the minimum amount of computation should be called for. A direct reading instrument with an accuracy of 5 per cent may, for example, sometimes be much more useful than one achieving an accuracy of 1 per cent but requiring complicated analysis of its readings. This point is well illustrated by several of the instruments to be described and particularly by that shown in fig. 78, which presents at one time a family of four characteristic curves of a germanium triode valve, thus giving a quick indication of the performance of the valve during its assembly without the necessity for tedious point-by-point measurements. Families of collector current/collector voltage curves are shown on the cathode-ray tube screen, either at four predetermined emitter currents or at four predetermined emitter voltages. The reverse current/voltage characteristic of either of the two "cat's whiskers" and the germanium base considered as a diode can also be shown. The optical system enables the traces to be copied on to a printed file card if they are required for future reference.

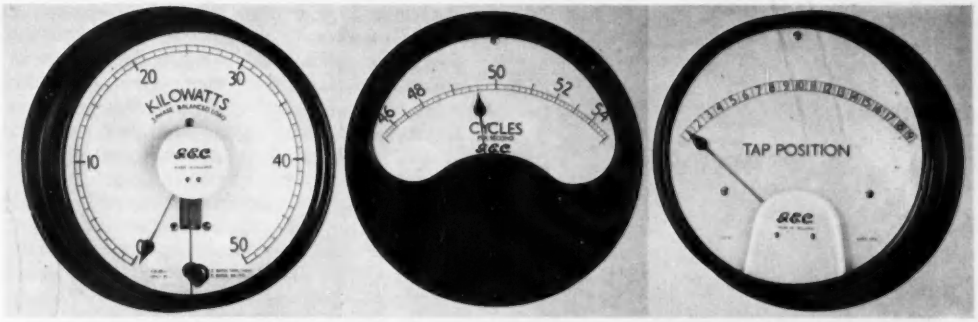

Fig. 77.—Examples of new switchboard instruments: (*left to right*) Projecting pattern all-glass front wattmeter; Protected flush type frequency meter; Projecting pattern all-glass front tap position indicator.

The miniature layer thickness meter (fig. 79) has been developed for the simple non-destructive measurement of the thickness of non-magnetic coatings on a ferrous base, and has many applications in the paint, metal spraying and plating industries. Three ranges are at present available, scaled for 0-5, 0-10, and 0-30 thousandths of an inch. In principle, the instrument is a moving-iron reluctometer: a specially shaped moving iron is mounted at the neutral axis of a powerful permanent magnet, one end of which projects through the instrument case and is fitted with a spherical tip of hardened steel. The moving iron, which is spring-controlled, takes up a position of equilibrium when the magnetic and control torques are equal and opposite. When, however, the spherical tip is placed on a coated ferrous base the flux distribution is changed and the moving iron takes up different stable posi-

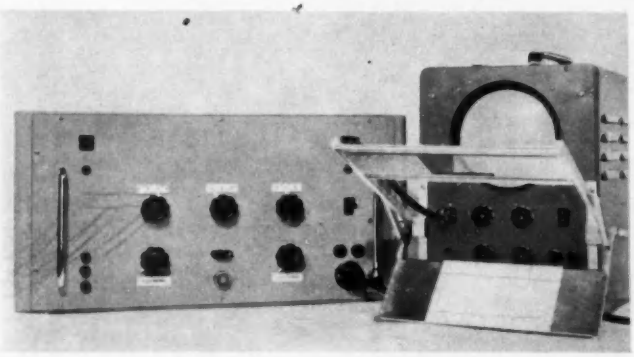

Fig. 78.—Germanium triode valve characteristic tracer.

tions depending on the thickness of the non-magnetic layer.

Two instruments which enable the current and power in a circuit to be measured quickly and to a fair accuracy are the link testing ammeter and the link testing wattmeter. When these are used it is not necessary to break the current circuit, the insulated links being closed

Fig. 79.—Miniature layer thickness meter.

around the cable or conductor as shown in fig. 80 ; the magnetic field in the instruments is produced between the ends of the laminated iron links inside the case. The ammeter movement is a spring-controlled moving iron, and that of the wattmeter, a spring-controlled moving coil with air damping. The movements plug into the moulded cases, the pins which make the electrical connections also serving to locate the movement between the pole pieces of the links. A series of interchangeable movements allows measurement of currents from 5 to 800 amperes and powers up to 200 kW, and the wattmeter is scaled both in kW and electrical horse power. The indicator units of the ammeter are available separately and may be plugged into the wattmeter links to obtain the current values, thus enabling the power factor to be calculated.

A V.H.F. impedance matching and measuring equipment, comprising an accurately-made coaxial transmission line with three adjustable voltage pick-up probes symmetrically spaced along its length, has been developed for use over the frequency range 70-90 Mc/s. The ratio of the voltages on the three probes is determined by an attenuator unit. Direct indication is given as to whether the load is matched or of a predetermined impedance, or, alternatively, the reflection coefficient set up by the load may be determined from the attenuator readings by means of charts supplied with the instrument. Reflection coefficients in the range 0·01 to 0·7 may also be measured, corresponding to standing wave ratios of 1·02: 1 to 5·6:1. This equipment is simpler and more rapid in operation than the slotted line, it is also smaller and therefore more readily portable, and it eliminates the errors due to variations of probe penetrations and eccentricity of the inner conductor. A new coaxial line with movable probes is being designed to extend the frequency range up to 500 Mc/s.

The design, manufacture and maintenance of a wide-band communications system such as a television relay link requires complex and specialised testing and monitoring equipment, and a complete range, including both radio and vision frequency apparatus, was developed for the London-Birmingham television link. One novel item is the linearity test unit, used to measure the dynamic amplitude linearity of a complete system. In this, a small 10 kc/s signal is swept across the amplitude range of the system by a low frequency sweeping voltage: at the receiving terminal the signals are separated and applied to the X and Y plates of an oscillo-

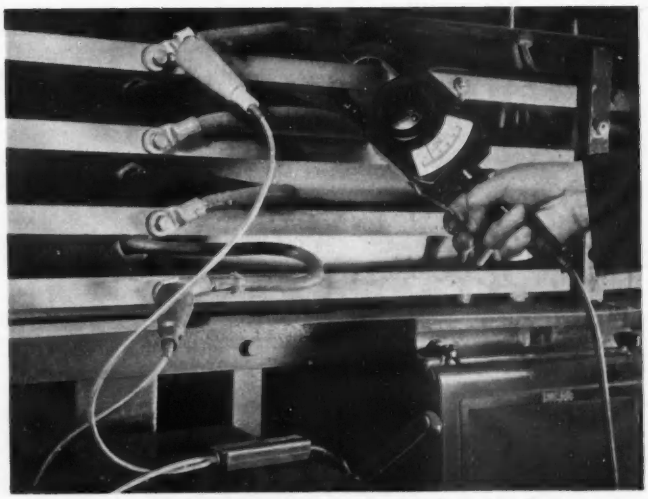

Fig. 80.—Link testing wattmeter in use.

graph, which then displays directly the linearity characteristic.

In such a system, too, the linearity of the phase-frequency characteristic is of great importance and this may be measured conveniently by the group delay measuring apparatus shown in fig. 81. Video frequency signals are amplitude modulated by a 60 kc/s signal, and to this modulated wave a further 60 kc/s signal is added from the same source. At the receiver the time displacement of the modulation and the 60 kc/s direct signal are presented in a cathode-ray oscillograph. Repetition of this process for different vision frequencies enables the phase-frequency characteristic to be obtained.

The calculation of complex electric fields by methods involving the mathematical solution of Laplace's equation is a laborious task, and for many years the use of an electrolytic tank analogue as an alternative method of solution has been widely employed. A knowledge of the path of the electrons in an electrostatic field is of greater importance than the determination of the field itself in solving many problems in electron optics, and for this reason the apparatus shown in fig. 82, based on a suggestion made by D. B. Langmuir* has been developed. It is an electrolytic tank which, with its associated equipment, provides an automatically-plotted record of the paths that would be taken by electrons in a field similar to that set up in the tank itself.

Fig. 81.—Group delay measuring equipment (Type II) in portable unit form.

The electron trajectory is determined by the normal gradient E_n and the potential V relative to the cathode, and these are measured by two probes in the surface of the electrolyte. The probes are linked by a gantry to the plotting mechanism, which is driven by a continuously steered trolley, the radius of curvature being determined by $2V/E_n$. This ratio is derived from voltages proportional to V and E_n fed to a potentiometer, the sliding contact of which is automatically driven to the balance position. The motion of the sliding contact is linked to the steering mechanism of the trolley by "Selsyn" motors, so that the radius of curvature is continually adjusted to plot the correct trajectory. This apparatus in its fully developed form will be a valuable aid to the design of electron guns and other devices where the trajectories of electrons are of primary importance.

In a different field of measurement an instrument has been developed for the continuous measurement of the diameter of machine-drawn glass tubing.† Numerous factors affect the diameter: in the Danner process these include the quantity, temperature and viscosity of the glass flowing on to the rotating mandrel, the air pressure down the mandrel, and the rate of drawing. The apparatus shown in fig. 83 enables these factors to be studied more closely and the diameter of the tubing to be controlled within closer limits. One important objective is the production of very uniform tubing for fluorescent lamps.

The instrument measures and records the diameter of glass tubing passing between two vertical rollers, the separation of which varies the inductance of two coils in a bridge circuit. The out-of-balance voltage is rectified, amplified by a magnetic amplifier, and presented on a recording milliammeter as a measure of the tube diameter.

The concentration of living bacteria in water or liquid foodstuffs is usually determined by

*D. B. LANGMUIR, *R.C.A. Review*, Vol. XI, No. 1, pp. 143-154, March. 1950.

†"Technical Control in Glass Manufacture," by J. H. PARTRIDGE and E. PRESTON, p. 216, *G.E.C. Jour.*, Vol. XVIII, No. 4, Oct., 1951.

distributing suitable dilutions of the material into liquid agar jelly in flat Petri dishes; the resulting " plate " is then incubated and the number of bacterial colonies counted, a typical test possibly involving the counting of several hundred colonies on each of eight plates. In a simple apparatus which reduces the counting time and eases the strain on the observer, the " plates " are illuminated by transmitted or oblique lighting, depending on the medium used, and the colonies are counted by means of a stylus pen. A switch mounted on the pen automatically operates a counter as each colony is marked. Two varieties of bacteria appearing on one " plate " may be counted with separate pens using differently coloured inks.

A modern feature of high-voltage power transmission is the growing use of gas pressure cable, in which the insulation is augmented by a filling of dry compressed inert gas. Arrangements for the maintenance of these cables must take into account the possibility of leaks occasionally occurring, and whereas the position of large leaks caused by mechanical damage is usually obvious the location of smaller leaks calls for considerable ingenuity. The leaking section is first identified by the loss of pressure in a reserve gas container. Nitrogen at about 1 atmosphere gauge pressure is then supplied to the cable section through a flow meter until a steady reading is obtained; the gas supply is then changed to hydrogen at the same pressure and a clock is started. When the nitrogen-hydrogen interface reaches the leak, the rate of flow increases and the clock is stopped. The process is repeated at the other end of the section and the ratio of the measured times gives the ratio of the two lengths of cable between the ends and the leak. As the total length of cable in the section is known the position of the leak may then be determined.

Progress in X-ray engineering is not necessarily confined to the production of more powerful or more fully automatic apparatus. Economic considerations have created a demand for equipment which, while capable of producing satisfactory radiographic results, remains within the purchasing power of the smaller hospital. The Watson " Roentgen 200 ", shown in fig. 84, is a full-wave generator designed to meet this requirement and also to satisfy overseas needs. It consists essentially of a four-valve transformer unit capable of delivering 100 kVp. at 150 mA., or 93 kVp. at 200 mA. The control unit incorporates a device which automatically indicates to the operator the maximum safe load factors for each of four possible tube foci.

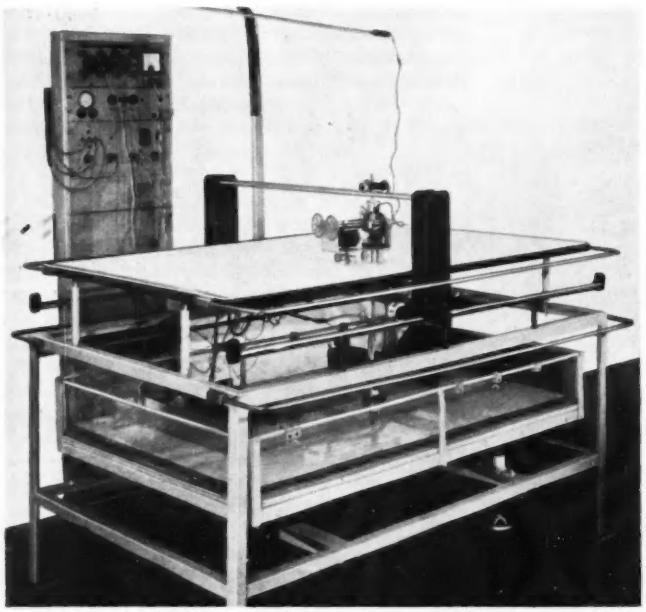

Fig. 82.—Apparatus for the automatic plotting of electron trajectories.

From the electrical standpoint the most novel and interesting feature of the apparatus is the timing system. In modern X-ray work exposures of two, three or four hundredths of a second are commonplace, but to time them with the requisite accuracy is an ever-present problem. The use of a synchronous motor timer does not furnish a complete solution, for, apart from the slight inaccuracies due to the timer and exposure contactors themselves, the magnetic state in which the core of the high-tension transformer is left at the end of one exposure will affect the duration of the next ; it also affects the amount of sparking at the contactor contacts and the surge overvoltage which is applied to the X-ray tube at the beginning of an exposure. These difficulties are overcome by providing, in the control unit, a relay sensitive to the magnetic

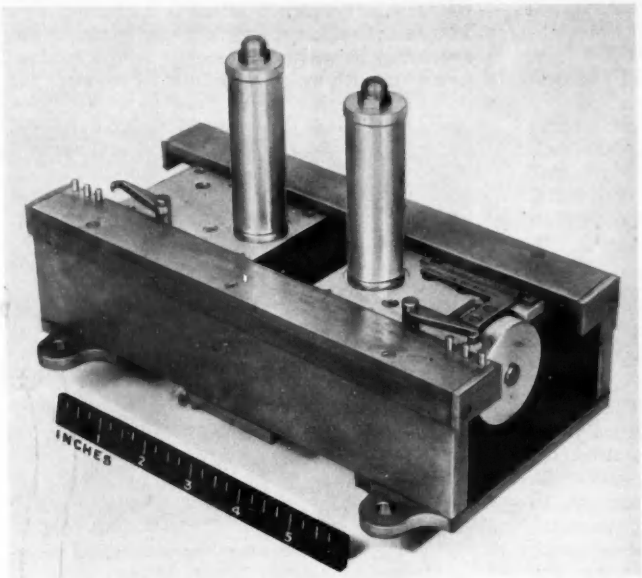

Fig. 83.—Instrument for continuous measurement of glass-tubing diameter.

state of the transformer core. This enables the contactor to adjust itself automatically so as to take account of the effects of any previous exposure on the magnetic characteristics of the transformer core. This, together with a phasing circuit which accurately phases the start of the exposure, reduces any current and voltage surges to negligible proportions and makes the timing system exceptionally accurate. Also included is a uniselector which provides a delay period of one second to allow the valve filaments to warm up from standby to working conditions, resets the mAS meter to zero before the exposure is made, and ensures that the exposure contactor coil is energised in the correct phase relationship.

TELECOMMUNICATIONS, VALVES AND RADIO.

TELEPHONES.

The design of modern telephone transmission equipment shows a trend towards the use of miniature components on plug-in panels and the inclusion of individual power units on the various equipment bays to give greater flexibility of power distribution. Each bay may then be connected to a socket carrying an A.C. supply, avoiding the necessity for the present rigid busbar systems and secondary battery apparatus.

Equipment is now available which enables up to 960 telephone circuits to be carried over coaxial cable in such a way that individual circuits can readily be broken off at intermediate points. Wideband amplifiers similar to those already manufactured for coaxial cable telephone systems have been supplied to the British Post Office for the Birmingham - Manchester television cable route, and others have been installed on the route that will carry television signals from London to Cardiff.

A modification of the frequency ranges occupied by the speech circuits in a three-circuit carrier telephone system has enabled the frequencies of a six-channel carrier-frequency telegraph system to be accommodated in the three-circuit range. This enables the normal three-circuit repeater to be used for amplifying both the speech and telegraph channels. So successful is the modification that in addition to

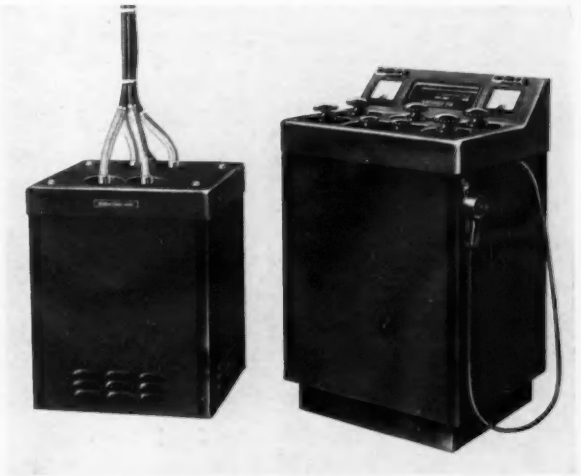

Fig. 84.—The "Roentgen 200" X-ray generator showing transformer unit and shockproof high-tension cables, together with mobile control table.

including six telegraph channels, all three speech circuits may now be transmitted with a high-frequency response extending up to 3·4 kc/s, which conforms to the latest C.C.I.F. recommendations for international speech circuits.

A new signalling system for telephone circuits employs a tone above the speech-band 300-3,400 c/s. This method can be used to transmit simply and effectively any form of primary signalling which produces two line conditions such as line loop and line disconnection, and is, therefore, particularly applicable to the transmission of the trains of pulses originated by the dial of an automatic telephone exchange.

For Electricity Supply Authorities a power-line carrier system, Type N, has been designed to provide a comprehensive means of communication over the actual power lines. The system is sufficiently flexible to satisfy not only the many present-day communications requirements but also those of the foreseeable future. The principles of carrier telephony are employed to provide a maximum of eight duplex communication circuits per system between terminal equipments ; each circuit passes, in each direction, a composite band of frequencies in the range 300-3,960 c/s, subdivided into one speech circuit, one signalling circuit and six super-audio telegraph channels suitable for teleprinter, supervisory control and indication, and remote metering systems.

On a Type N system the various carrier frequencies are checked occasionally and, if necessary, adjusted to within $\pm$ 1 c/s of their nominal value. As a conventional frequency standard accurate enough for this check would be very expensive and not portable, an oscillator synchroniser (fig. 85) has been produced for checking the 12 kc/s and carrier oscillators. In Europe it is normally tuned to a reference frequency of 200 kc/s from the B.B.C. transmitter at Droitwich, but any other radio-transmitted frequency which is a multiple of 4 kc/s and of sufficient accuracy may be used. The synchroniser, which will operate with a received signal strength as low as 50 μV, is compact and portable, may be mounted on a rack or in a cabinet, and is driven from A.C. mains.

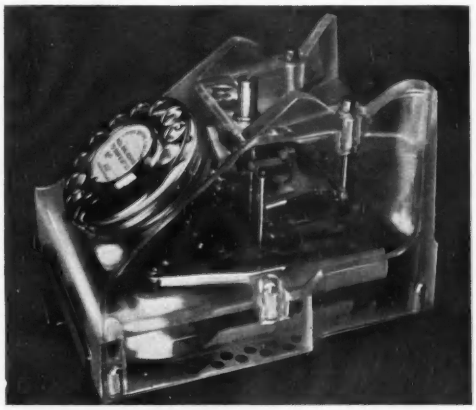

Fig. 86.—Latched-button telephone for individual metering, showing internal details.

Output from the oscillator under test is mixed with that from a harmonic generator (incorporated in the synchroniser) which produces a 4 kc/s harmonic sequence. The mixer output is taken to a Tuneray indicator which enables the oscillator frequency to be accurately adjusted.

The individual metering of telephone subscribers on multi-party lines is complicated by the identification methods devised in the past. Even when local calls are charged at a flat rate, identification of a party line subscriber is still necessary if any fully automatic scheme of toll and trunk calling is to be attempted. A simple, economic solution to this problem is afforded by an adaptation* of the latched-button telephone (fig. 86). The push-button which a party line subscriber is required to depress before dialling is used to send a signal to the exchange, actuating the appropriate meter, or recording the subscriber's number, as required. The apparatus needed at the subscriber's telephone is small enough to fit easily

Fig. 85.—Oscillator synchronising unit for type N power line carrier system.

*British Patent Application No. 13216/51.

into his instrument, and the system is completely guarded against fraud.

ELECTRONIC SWITCHING.

During the past year increasing effort has been applied to the development of electronic switching techniques for automatic telephone exchanges. The advantages of these methods over the mechanical devices at present in use include

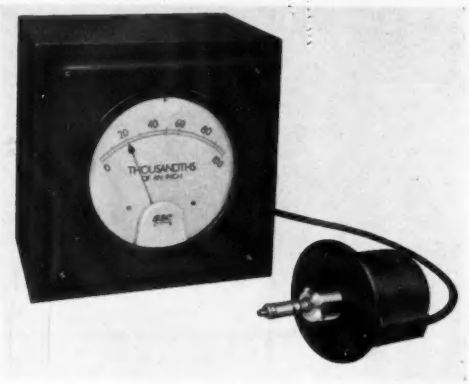

Fig. 87.—Electro-mechanical converter instrument.

much higher speed of operation, simpler maintenance and a greater degree of compactness. The main object has been the development of an electronic trunk routing exchange, but similar techniques are being used in the development of an electronic telemetering distributor capable of sending ten meter readings over a voice frequency telegraph channel for use in connection with the control of electric power networks.

The electronic trunk routing exchange is designed to handle trunk traffic where standard dialling pulses are used, a sequence of pulse trains being employed to route a call through a series of trunk exchanges. The first pulse train selects the desired outgoing route from the first exchange. The calling line is connected to a free line in that route during the short pause between pulse trains, and successive trains of pulses are thus sent on to further exchanges. Although it may be necessary to hunt over several hundred lines the connection is made easily by the electronic method within the time available. It is the development of cold cathode triodes and germanium diodes which has enabled the number of hot cathode valves required to be reduced sufficiently to bring the electronic exchange within the bounds of practical possibility.

Cold cathode diode and triode valves are also used instead of mechanical switches in the telemetering distributor. Although the apparatus as constructed at present can deal with up to ten meter readings its capacity could easily be extended. The readings to be transmitted are coded into binary numbers and fed to the distributor to be sent in turn at a speed suitable for a voice frequency telegraph channel; by this means the ten readings are transmitted in four seconds. At the receiver, which is synchronised with the transmitter, the code pulses are redistributed and decoded and operate slave meters. This application of electronic techniques to a telemetering system eliminates the need for rotary mechanical switches at a point in the system where they would be subject to continuous wear, thus giving greater reliability than is possible with the mechanical systems previously employed.

REMOTE INDICATING SYSTEM.

New equipment has been developed for measuring mechanical quantities electrically and for indicating the results at a distance (fig. 87). Operation is from A.C. mains and the indications may be transmitted over a considerable distance without auxiliary apparatus. A change of mutual inductance forms the basic principle. An entirely new magnetic powder core, "Gecalloy PL," is used in combination with an oval type of dynamometer indicating system. Overall accuracy is high, and is unaffected by variations

Fig. 88.—Table model television receiver.

of ambient temperature or by changes of up to 30 per cent of voltage and 10 per cent of frequency. Power consumption is very small ; the equipment contains no thermionic valves or rectifiers of any kind ; there are no amplifiers to maintain and no contacts to keep clean, neither is there a troublesome multiplicity of moving parts.

Television Receivers.

In response to public demand for a larger size of television picture, production has been concentrated on models equipped with 12 in. diameter tubes. A table model (BT 5144) and a console version (BT 4541) using the same receiver have been introduced. A filter screen giving improved viewing in daylight or bright artificial light, and affording truer picture tone values, is fitted to the console model, and this feature is also incorporated in another new table model (BT 5145). There has been a steady trend towards the use of higher EHT voltages to give a brighter picture and to take full advantage of the filter screen technique.

Receiver chassis design has continued to make use of an interchangeable sub-deck (fig. 88) on which the signal frequency section of the circuit is mounted. Each of the channels allocated to the five main television transmitters is covered by one of these assemblies and change of the frequency band, should the receiver be moved to a new reception area, is therefore simplified.

Fig. 89.—Three-speed auto-radiogram.

Fig. 90.—Battery-operated radio receiver.

Greater use has been made of germanium crystal rectifiers in place of thermionic valves, especially in the noise suppression circuits ; there has been considerable development work on these circuits, which have now been made more easily adjustable to suit local reception conditions. Other economies have been effected by the development of time base circuits requiring only one valve ; this principle has been used for the line time base in the latest table model receiver.

Cathode Ray Tubes.

The screen contour of the 12 in. television cathode-ray tube has been redesigned. The face is now almost flat and the picture can accordingly be viewed over a much larger angle than was previously possible.

A 16 in. diameter television tube has been developed. The screen has a radius of curvature of 27 in. across its face and the scanning angle has been increased to 70 degs. to reduce the overall length of the tube. This has necessitated the design of special deflector coils to overcome deflection defocusing and raster distortion. The neck diameter has also been increased slightly to prevent neck shadowing difficulties. For these tubes a new and less expensive glass, with no lead constituent, will be used.

Work on the electron gun has included investigations into the performance of an ion trap and the use of a valve-type cathode-heater assembly. The ion trap, one function of which is to prevent the back bombardment of the cathode by positive ions, also supplements the protection afforded to the phosphor by the aluminium layer on the screen. The alternative cathode-heater assembly permits the use of a 6·3 volt 0·3 amp. heater, similar to that used in receiving valves.

Life test facilities have been expanded to cater for the increased production of cathode ray tubes following the opening of the new Perivale Factory. The new racks each accommodate sixteen tubes in any of the sizes made, and provide a very wide range of operating conditions. The tube characteristics may be accurately measured without removing the tubes from the racks.

The range of specialised oscillograph tubes has been extended, the most important development being a two-gun tube with a 6 in. diameter screen and two completely independent electrostatically focused and deflected electron beams. Each deflector plate is brought out to a separate connection and all the leads emerge through the base of the tube. This type is being made with the usual range of fluorescent screens.

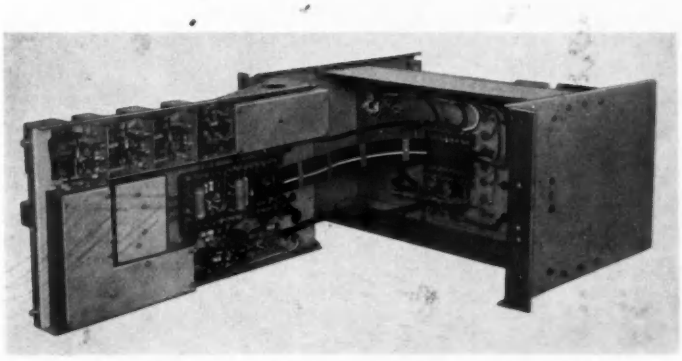

Fig. 91.—F.M. V.H.F. transmitter, showing chassis swung open for easy inspection.

RADIO BROADCAST RECEIVERS.

The use of all-glass miniature valves, which is now common in television receivers, has been extended to all types of radio receiver for the home market. Quite apart from the benefits of their small size, the fact that all electrical connections are brought out to the base of the valve is of advantage in the layout of circuits.

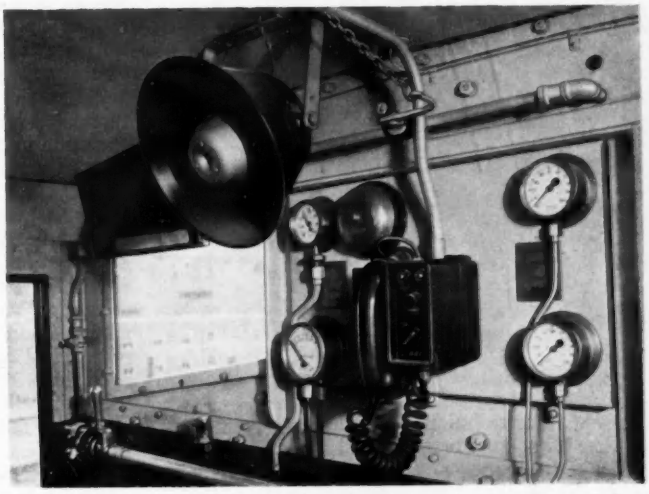

Fig. 92.—Heavy duty V.H.F. equipment installed in a locomotive of the Steel Company of Wales.

To enable both long-playing and the normal type of gramophone records to be played the BC 9239 Radiogram (fig. 89) has been equipped with a multi-speed auto-change motor. Two interchangeable pick-up heads are provided, with different needle points to suit the standard 78 r.p.m. groove and the 33⅓ r.p.m. low - speed "microgroove" records respectively. The motor is also arranged for operation at 45 r.p.m. to cater for records played at this speed should they be introduced into the home market.

Extended use has been made in the export field of a cheapened form of band-spread tuning first brought into use in less expensive types of receiver some two years ago. The short

wave broadcast bands are first selected by a "detent" locating device on the main tuning condenser; fine tuning on the bandspread principle is then accomplished with an auxiliary

Fig. 93.—Communications receiver.

control. This technique has proved so successful that it has now been extended to the higher grades of receivers. The detents have been made adjustable to allow more accurate station setting on individual receivers and the principle has been applied to all the tuned circuits. In the highest grade of receiver it covers all the short wave bands. The tuning dial has been enlarged considerably to enable full advantage to be derived from the improved tuning facilities.

A new 4-valve, 2-band, superhet receiver (BC 2147), operating from dry batteries only, has been introduced, with the novel design feature of a metal cabinet in a decorative colour (fig. 90). Large numbers are now in use in such main markets as India, Pakistan, and Singapore, its low price having brought it within reach of the poorer classes.

Radio Communications.

Developments of trunk radio systems on the V.H.F. bands have continued. Compact A.M. or F.M. V.H.F. systems (in the case of the F.M. equipment capable of carrying 4 speech channels), have been evolved for use where the more flexible 24-channel apparatus is not required. They comprise transmitters and receivers in the range 70 to 184 Mc/s with integral power units for 200-250 volts, 40-60 c.p.s. A.C. mains. Crystal control of frequency is employed. A low level of unwanted radiation from the transmitters, and exceptional freedom from spurious responses in the receivers, enables a number of these equipments to be used in the same locality, and there is provision for free air circulation round all components to ensure satisfactory operation in tropical countries (fig. 91).

An example of continued progress in the development of V.H.F. mobile equipment for industrial and other specialised applications is the installation of heavy duty apparatus on locomotives used by the Steel Company of Wales (fig. 92). The equipment has been designed for use on steam, diesel and diesel-electric locomotives and is robust enough to withstand mechanical shocks and vibrations in shunting operations, even when the locomotive is being used virtually as a battering ram. It can also withstand the dust, heat and fumes experienced in foundries.

The performance of the normal type of communications receiver (BRT 400D) has been further improved. This equipment (fig. 93) has been adopted as standard by the Swedish armed

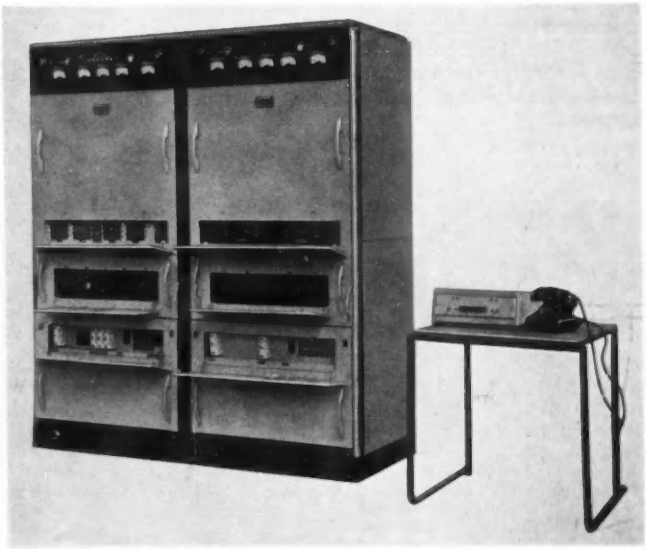

Fig. 94.—1 kW amplitude-modulated H.F. transmitter.

forces and is also being used extensively by the B.B.C. and many Government departments in this country and overseas. A new model incorporates such refinements as facilities for frequency shift keying and a crystal calibration with a 500 kc/s spacing.

The new 1 kW amplitude-modulated high-frequency transmitter (fig. 94), four of which have been supplied to the Indian State Railways for point-to-point radio communications, covers the frequency range of 2-17 Mc/s as either a telegraph or telephone transmitter and operates from three-phase, 400 volt mains. It is designed for unattended operation and is fitted with automatic tuning mechanism enabling it to be switched to any one of six pre-selected carrier frequencies. All components are very generously rated, eliminating excessive maintenance, and built-in metering and monitoring facilities enable performance to be checked regularly and any fault localised without dismantling the equipment.

Thermionic Emission Research.

It is axiomatic that the cathode of a thermionic radio valve shall continue to provide an adequate supply of electrons throughout the operational life of the valve. As valves become smaller one must accept more onerous conditions as regards the power loading of the electrodes, with the further possibility of an increase in the density of the electron current from the cathode. These requirements can clearly be met only if the fundamental processes of electron emission are well understood. Intensive research in this field has been in progress at the Research Laboratories for a number of years. Its chief purpose has been the investigation of cathode coatings such as the barium strontium oxide coating widely used in the lower power valves and the thoria coating used in some of the higher power types.

Other types of complex surface which are used to give high secondary and photo-emission have been investigated, as well as the passage of current through the layers and the electron emission from them. High coating resistance leads to heating effects at high current density and there are often marked variations in emission with time, some being due to changes in the state of the material when current passes through it. Since these changes may involve actual decomposition of the coating they must be minimised. Another factor is that the dielectric and resistance properties together determine the effect of a high electric field on the emission and influence the electrical breakdown characteristics.

For these reasons the materials must be studied as electrical conductors, introducing present-day semi-conductor theories. These theories must also be applied to the junction between the emissive coating and the underlying supporting metal (the core metal), since rectifying effects may be introduced there. This is particularly noticeable when chemical reaction between the coating and the metal forms layers which have a resistance higher than that of the coating itself. Studies of this kind have enabled the most suitable core metals for use with oxide coatings to be determined.

The conductivity and emission of coatings have been established under the most rigorous experimental conditions now available, and have been related to the electron density in the coatings and to the density of the free barium providing the electrons. At 1,000 degs. K. the highest conductivity obtainable is nearly 10^{-2} ohm^{-1}, cm.$^{-1}$, and the highest emission is about 10 amps./cm.^{2}

A study of secondary emission effects has given further information about electron and ion movements in the coatings and has led to a detailed examination of decomposition processes. These are important not only in the emissive layers, but also in the poorly conducting

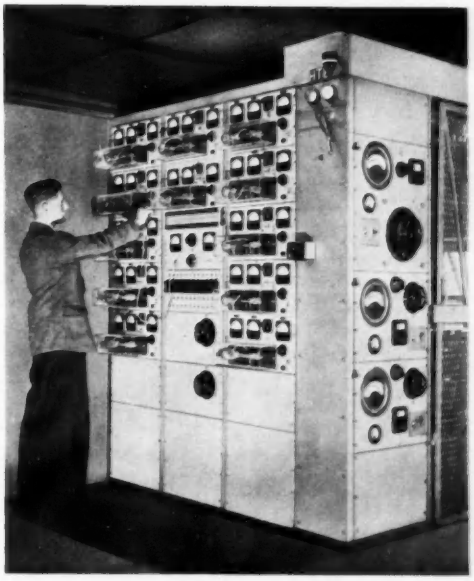

Fig. 95.—Equipment for life testing small, disc-seal triodes for use in trunk-radio apparatus.

barium compounds which, having formed on valve electrodes during processing, decompose on electron bombardment and form gases which depress the emission. Electrode treatments to minimise these formations have been investigated.

Studies are in progress of other causes of poor emission including the effects of gases. Also the rates of formation, diffusion and evaporation of barium in different types of coating have been measured. The work has established the emission values, in the best activated state, of mixtures of barium, strontium and calcium oxide over the whole possible range of coating composition. It has been shown that a maximum occurs at the molecular proportion : barium 48 per cent, strontium 42 per cent and calcium 10 per cent. The operational life and the resistance of these mixtures to treatments which tend to depress emission are also being investigated.

Valve Life-test Equipment.

A previous Progress Article* contained a brief reference to new equipment for life-testing

G.E.C. Jour., Vol. XVII, No. 1, p. 40, January, 1950.

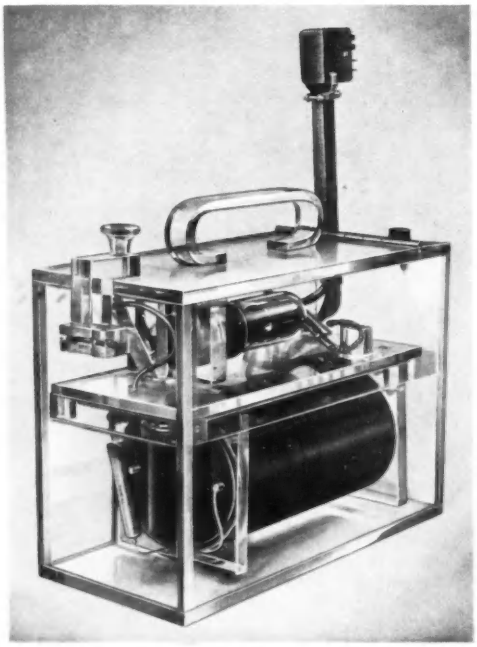

Fig. 96.—Unit for life-testing small high-tension rectifier valves.

receiver valves at the Research Laboratories. Up-to-date apparatus for testing transmitter valves has now been installed. Safety enclosures for the protection of the operators are used, housed in a specially screened room to prevent the free radiation of radio-frequency energy.

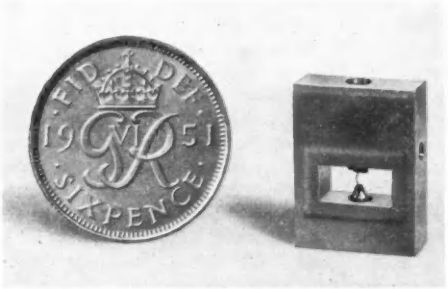

Fig. 97.—Silicon mixer crystal compared in size with a sixpenny piece.

Fig. 95 shows another new piece of transmitting valve-test equipment built during the year. This is for establishing the life of small disc-seal triodes for use in trunk-radio apparatus. Specifications call for a minimum life of 10,000 hours and extremely accurate life-test evidence is necessary. Special precautions have been taken to ensure that the test equipment itself will give a very long period of trouble-free operation, and the valve characteristics may be measured without removing the valves from their circuits.

A special unit (fig. 96) has been developed for life-testing the small high-tension rectifier valves used in television receivers. The valve and its associated transformer, load resistor and condenser are housed in a " Perspex " box, and high-frequency power from the local valve oscillator is supplied through a multicore cable which also carries lines for metering purposes. The box may be filled with oil to reduce tracking at very high voltages and to prevent the deterioration of the performance of the equipment itself during life.

Geiger Counter Tubes.

The main development in Geiger-Muller Counter tubes has been the adoption of a different organic quenching agent for the gas filling. It has been found that ethyl formate vapour has numerous advantages over the conventional ethyl alcohol filling previously used : for example

a better plateau characteristic is obtained, and tubes may be operated down to —20 degs. C. as against the previous minimum temperature of 5 degs. C. Furthermore, the variation of operating voltage with temperature is only a quarter of that observed when ethyl alcohol is used, giving a corresponding improvement in the accuracy of measurement. The end window flanges of all types of the 1 in. diameter counter tubes have been standardised to 36 mm. maximum diameter, thus permitting the same fixing arrangements to be used for the various types. A different anode terminal seal has been introduced to allow direct soldering or clamping of the connection.

Crystal Diodes and Triodes.

The silicon mixer crystal has now been brought into use in the millimetre wave band, and fig. 97 shows a type (SIM 8) designed for a wavelength of approximately 8 mm. It consists of a section of wave guide across which are connected the "whisker" and crystal.

Studies of new methods of preparing germanium have led to the production of a new type of germanium rectifier (GEX 64) with an extremely low forward resistance. This type is eminently suitable for use as a modulator in carrier telephony and for this purpose is now replacing the copper oxide version.

Considerable progress has been made in the development of the germanium triode but numerous problems are still to be solved before large scale production can begin. Investigations have shown that it is possible to construct a radio receiver using germanium triodes instead of the usual thermionic valves, able to give adequate sound output from a loud speaker for normal listening. Although the receiver (fig. 98) requires no filament heating power it does need a small H.T. battery or an equivalent A.C. mains rectifier unit, which, incidentally, may itself utilise germanium diodes as rectifiers.

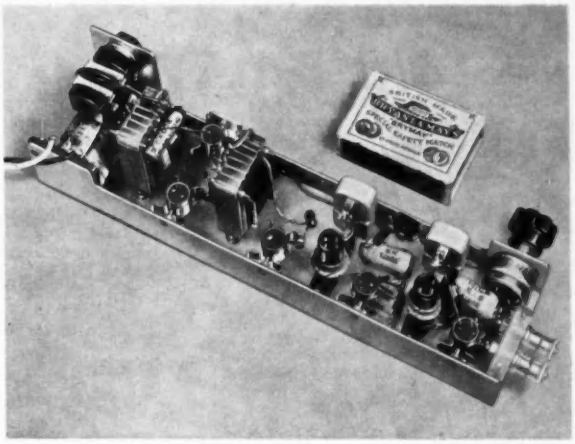

Fig. 98.—Radio receiver using germanium triodes instead of thermionic valves.

TECHNICAL LITERATURE

A DIGEST OF RECENT BOOKS, ARTICLES AND PAPERS, BY MEMBERS OF THE G.E.C. AND ITS ASSOCIATED COMPANIES.

AXIAL FLOW FANS: DESIGN FOR PRODUCTION

By R. H. Holbeche, A.I.E.E., M.I.H.V.E. (Woods of Colchester).

Jour. Inst. Heating and Ventilating Engineers, Vol. 18, No. 180, July, 1950.

The author sets out the problems associated with standardisation for quantity production.

A performance prediction system is a desirable basis for a production plan. It entails the adoption of impeller diameters in a geometric, as distinct from the usual arithmetic, progression. Each impeller in the series must exactly conform to a "family" characteristic.

The author brings forward the little-known fact that 40-, 50- and 60-cycle A.C. speeds approximate to a geometric progression which can be applied with advantage to the impeller diameters.

A performance prediction system is introduced whereby the "family" characteristic is drawn upon a transparent "cursor" which moves over a ground chart on which volume and pressure are scaled logarithmically together with lines corresponding to the impeller diameters and to A.C. motor speeds. This forms also a practical basis for production in conjunction with adjustable impellers, the characteristics of which are discussed.

For the quantity production of axial-flow fans having higher pressures, the advantages of the contra-rotating principle are demonstrated. The paper concludes by referring to the desirability of designing special motors for axial-flow fans.

ELECTRIC FURNACES

By D. M. Dovey and I. Jenkins (Research Laboratories).

Progress Review No. 16, Jour. Inst. Fuel, May, 1951.

A survey of the electrical methods of heating in use in industry to-day. The equipment described includes induction and dielectric heating furnaces, arc furnaces, resistor furnaces, both batch and contin-

uous types with or without controlled atmospheres, salt baths and radiant heating plant.

SOME EXIGENCIES OF WAR TIME

By H. Cobden Turner (Salford Electrical Instruments Ltd.)

Presidential Address to the Manchester Technology Old Students' Association, February, 1950.

The speaker deals with a number of products and materials of fundamental importance, formerly obtained from abroad, which were denied to Britain during the war and for which substitutes had to be speedily produced in this country. These include such things as diamond dies, optical devices, ball bearings, special alloys, synthetic rubies and sapphires, to mention but a few. With the help of many detailed illustrations the means are illustrated by which all these specialised materials and devices were produced, the final product being in many cases superior to the original. The speaker concludes by urging young physicists to engage in this type of research which, besides being of absorbing interest, would undoubtedly be of great material assistance to the country.

THE DEVELOPMENT OF END-WINDOW GEIGER-MUELLER COUNTER TUBES (437)*

By R. O. Jenkins (Research Laboratories).

Proc. I.E.E., Vol. 98, Part II, No. 62, pp. 231-236, April, 1951.

This paper gives an account of various stages in the development of end-window self-quenching Geiger-Mueller counter tubes for the detection of β-particles. The original tube embodied a feather edge glass seal which later was replaced by an all-metal construction using a Kovar eyelet seal. The end windows to admit the β-particles were made either of copper or duralumin foil or mica, the latter being attached by a thermosetting plastic. Pumping and gas filling was found not to be as critical as for most vacuum devices, but cleanliness of the inside of the tube, and freedom from loose particles was essential.

CRYSTAL DIODES (440)*

By R. W. Douglas and E. G. James (Research Laboratories).

Proc. I.E.E., Vol. 98, Part III, No. 53, pp. 157-183, May, 1951.

The paper gives the current views of the manner in which very small amounts of impurities give rise to the special electrical properties of semi-conductors, and of the mechanism of contact rectification. The preparation of germanium and silicon for use in crystal diodes is considered and the steps found necessary in the processing are discussed in terms of the theoretical ideas.

In the second part of the paper, the design and performance of (*a*) a new coaxial-type silicon-crystal diode intended for use as a mixer at frequencies up to about 10,000 Mc/s, (*b*) a wire-ended germanium-crystal diode, are described and discussed. Particular attention is given to the frequency dependence of the rectification efficiency of the germanium diode, and its application as a replacement for the thermionic diode.

RADIO VALVE LIFE TESTING (442).*

By R. Brewer (Research Staff of the M.-O. Valve Co., at the G.E.C. Research Laboratories.)

Proc. I.E.E., Vol. 98, Part III, No. 54, pp. 269-277, July, 1951.

With the rapid growth in the use of valves for electronic equipment other than for entertainment purposes, the performance given by valves during their life has assumed considerable importance. The paper gives an account of valve life-testing practice which has evolved during the past twenty-five years, and outlines possible developments which may be undertaken in the techniques used for such tests.

OPTIMUM SPACING OF BROADCAST TRANSMITTERS (446).

By D. C. Espley (Research Laboratories).

Wireless Engineer, Vol. 28, pp. 37-39 (1951).

It is known that the interference range of a radio transmitter extends, to some extent, beyond the limits of the effective service area. The unique solution is given of the geometrical problem in which it is desired to know the number of different stations necessary to cover an unlimited territory for a given ratio of service range to interference range. The shape and extent of a finite territory have some effect on this number.

SOME RARE EARTH ACTIVATED PHOSPHORS (447).

By H. G. Jenkins and A. H. McKeag (Research Laboratories).

Jour. Electrochem. Soc. (America), Vol. 97, No. 12, December, 1950.

Two classes of rare earth activated phosphors having interesting and unusual properties are described. The first series, consisting of alkaline earth silicates activated by divalent europium, shows a wide range of fluorescent colours when excited by 3,650 Å radiation. Some of these compounds are characterized by the stability of their fluorescence at comparatively high temperatures.

The second class of phosphors, consisting of alkaline earth pyrophosphates activated by dysprosium and samarium, has unusual phosphorescent characteristics when excited by cathode rays.

THE DESIGN AND OPERATION OF TELEVISION CATHODE RAY TUBES (448).

By L. S. Allard (Research Laboratories).

Journal of the Television Society, Vol. 6, No. 3 (1951).

Various forms of electron guns are described for use in cathode ray tubes, and the reasons for the choice of the "all-magnetic" gun are given. The design features considered in detail are the triode section with its effect on beam angle focusing and deflection. The differences in the field strength necessary for focusing both triode and tetrode tubes are explained together with a method for ensuring that the axis of the focusing field and the axis of the beam are coaxial. The design of deflector coils is discussed with particular reference to the methods employed for obtaining uniform fields. Screen curvature plays an important part in the resulting picture quality, and usually a compromise has to be accepted between scan distortions and focus uniformity.

INDUCED GRID NOISE AND NOISE FACTOR (449).*

By R. L. Bell (Research Staff of the M.-O. Valve Co., at the G.E.C. Research Laboratories).

Proc. I.R.E., Vol. 39, No. 9, pp. 1059-1063, September, 1951.

In this paper there is developed an approximate treatment of narrow-band triode noise factor, taking into account induced grid noise by a new method. Minimal values of noise factor predicted theoretically are compared with experimental values and it is found that from a knowledge of circuit losses, shot noise, mutual conductance, space charge input capacitance, and D.C. grid current measured on the tube, noise factor, and optimum source conductance can be predicted with accuracy over a wide range of operating conditions.

It is shown that lead inductance effects and normal induced grid effects (grid noise, space-charge capacitance, transit-time damping) have no influence on noise performance, but merely affect tube admittances. Direct compensation in the grid circuit of components of input admittance to which these effects give rise leads to a deterioration of noise factor usually attributed to grid noise.

It is shown that the optimum grid circuit detuning may be provided automatically by the input space-charge capacitance.

SWITCH AND STORAGE TUBES (450).

By L. S. Allard and R. T. Hill (Research Laboratories).

Wireless Engineer, 28 (June, 1951).

A selection of switch tubes has been designed in which all the tubes are electrostatically focused while the deflection is either electromagnetic or electrostatic. They are all essentially high-impedance devices, and have been used in various applications, for example, obtaining a time sequence of pulses, angular discrimination, multiplication, and the analysis of the energy spectrum of particles resulting from nuclear disintegration.

The development of cathode-ray storage tubes has proceeded along two main lines, namely, for use with digital computors and for radar purposes. A number of such tubes are described in detail.

WIDE-RANGE VARIABLE FREQUENCY OSCILLATOR (452).*

By A. Cormack (Research Laboratories.)

Wireless Engineer, Vol. XXVIII, pp. 266-270, September, 1951.

A phase-shift oscillator is described, which has been made to operate up to approximately 180 Mc/s. Bandwidths in excess of one octave can be obtained and the amplitude of oscillation remains substantially constant over most of the range. The frequency of oscillation is controlled electronically, thus making the oscillator very suitable for use as a swept oscillator.

WAVEFORM SYSTEMS AND "TIME EQUALISERS," THEIR TRANSMISSION CHARACTERISTICS (453)*.

By D. C. Espley (Research Laboratories).

Wireless Engineer, Vol. XXVIII, pp. 251-258, August, 1951.

This paper describes a new approach to the solution of several of the outstanding problems in circuit theory where the available transmission information has been given in terms of distorted waveforms. It is shown that some of the classical transform concepts relating "frequency" and "time" characteristics can be replaced by much more straightforward algebra in which the physical interpretations are constantly in view.

Extensions of the method give practical solutions for the waveform properties of any number of systems working in tandem, or for any fraction of a known system. In these cases it has been found unnecessary to revert to frequency characteristics as the manipulations are carried out directly in terms of the echoes, or individual parts of the waveform distortions.

It is suggested that there are appropriate rôles for "time equalisers" and the better known "steady-state" equalisers, but the correction of some systems may require the use of both types of networks.

FREQUENCY STABILISATION BY MICROWAVE ABSORPTION (455).*

By H. R. L. Lamont (Research Laboratories).

Physica, Vol. XVII, No. 3-4, March-April, 1951.

The paper describes a method of stabilising the frequency of an oscillator by means of microwave absorption lines. Stabilisation has been obtained for a number of ammonia lines near 1·25 cm. wavelength, and a stability of $\pm$ 6 parts in 10^7 measured. Possibilities for other wavelengths are considered.

THE DIMMING OF LOW-PRESSURE DISCHARGE LAMPS (456).*

By C. E. Williams (Research Laboratories).

Proc. I.E.E., Vol. 98, Part II, No. 64, pp. 495-509, August, 1951.

The fundamental requirements for the satisfactory dimming of low-pressure hot-cathode and cold-cathode fluorescent lamps are discussed. D.C. operation is first considered, and the treatment is then developed to cover A.C. circuits. Lamp stability is considered from the points of view of smooth control of current, supply-voltage variation, and intermittent extinction. Lamp circuits are generalised in terms of Thévenin's theorem, and the ideas of voltage control and impedance control are introduced. Practical circuits are discussed, the difficulties of multiple-lamp control, and the means for overcoming these being mentioned. The separate-impedance method of control is described by reference to several circuits, and methods of unifying the control are suggested.

SOME FACTORS IN PICTORIAL REPRODUCTION PROCESSES WITH SPECIAL REFERENCE TO TELEVISION (457).

By R. G. Hopkinson, R. B. Mackenzie, and R. D. Nixon (Research Laboratories).

The Photographic Journal, Vol. 91B, pp. 2-10 (1951).

In a television system, as in the general run of photography, the purpose is not so much the achievement of a true reproduction process, as the production of a picture which is satisfying to the viewer. A discussion of the factors which determine the quality of pictorial reproduction in general is followed by a discussion of the application of these factors to television practice. The conclusion is reached that the factors governing the production of a satisfying picture must be solved by a carefully planned series of subjective appraisals.

THE LONDON-BIRMINGHAM TELEVISION RADIO - RELAY LINK (458).*

By R. J. Clayton, D. C. Espley, G. W. S. Griffith and J. M. C. Pinkham (Research Laboratories).

Proc. I.E.E., Vol. 98, Part I, No. 112, pp. 204-227. July, 1951.

The paper describes the television radio-relay link designed to convey the television-programme signal between London and Birmingham. It was installed initially to transmit this signal on a reversible one-way basis (the Part I system) in time for the opening of the Sutton Coldfield television transmitter in December, 1949. This facility is being followed by a modification to the system so that signals can be transmitted in both directions simultaneously (the Part II system.). The design has been strongly influenced by the requirement that all terminal and repeater stations should work unattended. This feature demanded the provision of an elaborate supervisory and monitoring system and the installation of a complete range of standby equipment in all the signal and power circuits of the stations.

V.H.F. COMMON AERIAL WORKING (459).*

By E. G. Hamer (Research Laboratories).

Electronic Engineering, Vol. XXIII, No. 281, pp. 244-249, July, 1951.

The paper gives an account of simple filters that have been developed for operating several transmitters and receivers from the same aerial in the band 70-90 Mc/s. with various frequency separations.

LUMINESCENT MATERIALS AND THEIR APPLICATION TO CATHODE RAY TUBES (460).

By A. H. McKeag and E. E. Welsh (Research Laboratories).

The Industrial Chemist, Vol. 27, No. 314, pp. 110-114 and 171-178 (1951).

The properties of the more important classes of phosphors are described together with modern techniques of application to the screen surface. The advantages of using aluminised backings to the phosphor screens to improve picture quality are also discussed.

PIEZOCRESCENCE—THE GROWTH OF DAUPHINÉ TWINNING IN QUARTZ UNDER STRESS (461).*

By L. A. Thomas (Research Laboratories) and W. A. Wooster (Brooklyn Crystallographic Laboratory, Cambridge).

Proc. Roy. Soc. A., Vol. 208, pp. 43-62, (1951).

It has been found that Dauphiné twinning can be created, modified,

or in some instances eliminated, by the subjection of α-quartz specimens to stress produced by mechanical or thermal means. The experimental observations can be explained in terms of a reversible phenomenon, the growth of one crystallographic orientation out of another under the influence of stress, for which the term *piezocrescence* is proposed.

THE MEASUREMENT OF MICROPHONY IN VALVES (462).*

By R. Bird (Research Staff of the M.-O. Valve Co., at the G.E.C. Research Laboratories).

Electronic Engineering, Vol. 23, November, 1951

The paper is an attempt to describe some of the methods now available for a more searching investigation into the nature and causes of microphony.

AN X-RAY STUDY OF TIN-NICKEL ELECTRODEPOSITS (463)

By H. P. Rooksby (Research Laboratories).

Jour. Electrodepositors' Tech. Soc., 27 (1951).

An X-ray investigation of the crystal structure and textural properties of tin-nickel alloy electrodeposits is described. A metastable nickel arsenide type structure characterises the alloy electrodeposit, which is stable up to 300 degs. C but decomposes on heating above this temperature. A strongly marked preferred orientation texture is found in bright tin-nickel electrodeposits, and an analogy with bright speculum is evident.

PULSE DISTORTION (464).

By S. H. Moss (Research Laboratories).

Proc. I.E.E., 98, Part IV (1951).

It is shown that for waveforms of simple shapes certain features may be defined: "content," "epoch," "spread," "skewness," "squatness," etc., which are affected in a very simple way by passage through a linear system. In fact, by proper definition, they are affected only additively by constants which are independent of the applied waveform, and characteristic only of the system. These invariants for the pulses and for the system correspond to the cumulants used to describe statistical distributions. With due care, these results can be usefully generalised for A.C. wavepackets.

THE DETERMINATION OF GERMANIUM (467, 468 and 469).*

By H. J. Cluley (Research Laboratories).

The Analyst, Vol. 76, No. 906, pp. 517-536, September, 1951.

PART I: TITRATION OF MANNITO-GERMANIC ACID (467).*

In aqueous solution germanium dioxide reacts with mannitol to form a strong, complex acid; germanium can be determined volumetrically by titration with sodium hydroxide solution of the mannito-germanic acid so formed. A method has been evolved in which the volumetric procedure is applied after a preliminary separation of the germanium by precipitation as sulphide. By a simple modification the interference of arsenic is readily obviated.

PART II: ABSORPTIOMETRIC DETERMINATION WITH PHENYLFLUORONE (468).*

An absorptiometric method is described for the determination of germanium by means of 2 : 3 : 7—trihydroxy - 9 - phenyl - 6 -fluorone (phenylfluorone). The method is about four times as sensitive as the molybdenum blue method. By a simple distillation from hydrochloric acid solution the germanium is readily separated from the few elements that have been found to interfere with the phenylfluorone method.

PART III: DETERMINATION IN FLUE DUST, COAL AND COKE (469).*

The author's absorptiometric method for the determination of germanium with phenylfluorone has been applied to the analysis of flue dusts. The high sensitivity of the absorptiometric procedure permits the use of samples weighing 0·1 g. or less, and this greatly facilitates the decomposition of the sample by sodium carbonate fusion. Duplicate determinations can be completed in 3 to 3½ hours.

The absorptiometric procedure has also been applied to the determination of germanium in coal and coke. In one method the sample is decomposed by a procedure similar to the Eschka method for the determination of sulphur in coal. In a second method the sample is decomposed by combustion in a bomb calorimeter. Samples of coal and coke examined by these methods were found to contain seven to twelve parts of germanium per million.

ALUMINIUM-BACKED SCREENS FOR CATHODE RAY TUBES (474).

By R. W. Dudding (*Research Laboratories*)

Brit. I.R.E. Radio Convention, 1951.

The demands of modern television reception have necessitated the use of the "all-magnetic" cathode ray tube in receivers. The ion-burn screen blemish associated with the all-magnetic tube can be prevented by depositing a thin layer of aluminium on the back of the phosphor coating. The characteristics required by such a layer, and methods of preparing it, are described in this paper. Further advantages of the aluminium-backed screen, among them the prevention of screen voltage saturation effects and improved brightness and contrast, are described and explained.

RARE METALS IN ELECTRON TUBES (475).

By D. A. Wright (Research Staff of the M.O. Valve Co. at the G.E.C. Research Laboratories).

Brit. I.R.E. Radio Convention, 1951.

The paper discusses some of the problems arising in the manufacture of electron tubes, and shows how the use of rare metals assists in overcoming some of the difficulties, or is necessitated by the nature of the problems. Typical cases referred to are: electrodes for operation at high temperature; improvement of vacuum by the use of getters; production of high thermionic secondary and photo-emission; reduction of electron emission from grids; and the use of rare metals in brazing and soldering.

The properties of the rare metals, which make them useful in dealing with these problems, are described and in a few cases reference is made to the preparation of the metal concerned.

SEMI-CONDUCTORS

By D. A. Wright (Research Staff of the M.-O. Valve Co., Ltd., at the G.E.C. Research Laboratories).

Methuen & Co., Ltd., 36, Essex Street, Strand, W.C.2.

New York: John Wiley & Sons (Inc.)

viii, 130 pp., 32 diagrams. Price 7s. 6d.

(Methuen's Monographs on Physical Subjects.)

This monograph gives an account of the basic theory of semi-conductors, intended to serve as an introduction to the subject for students at or near degree level. Although most aspects are touched upon, the emphasis is on electron emission processes from semi-conductors, and on the comparison of these with the behaviour of metals.

*** A limited number of reprints is available of those papers marked with an asterisk. Copies may be obtained on application to the Editor, G.E.C. Journal, Magnet House, Kingsway, W.C.2.**